Contractor's Report to the Board

Landfill Facility Compliance Study Task 6 Report—Review of MSW Landfill Regulations From Selected States and Countries

August 2004

Produced under contract by:

GeoSyntec Consultants, Inc.
Oakland,California

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The information contained herein is based on an interpretation by the contractor of existing regulations and documentation available on the topics discussed, available at the time the report was written. The statements and conclusions of this report are those of the contractor and not necessarily those of the Integrated Waste Management Board, its employees, or the State of California. The State makes no warranty, expressed or implied, and assumes no liability for the information contained in the succeeding text.

1 Executive Summary

This report presents the results of work completed by GeoSyntec Consultants (GeoSyntec) under Task 6 of the Landfill Facility Compliance Study, California Integrated Waste Management Board (CIWMB), contract number IWM-C9047.

The landfill study consists of two phases. Phase I includes Tasks 1–3 (compiling a checklist of pertinent environmental regulatory requirements, developing a cross-media database inventory of 224 California municipal solid waste [MSW) landfills, and assessing MSW landfill environmental performance for the time period from January 1998 through December 2001). Phase II consists of Tasks 4–8 (these tasks include assessing the effectiveness of current regulatory requirements in controlling environmental impacts over time and identifying possible ways to improve regulations to provide for greater environmental protection).

In accordance with the contract scope of work, Task 6 is comprised of the following activities:

- Review current MSW landfill regulations from all 50 states and selected countries to identify those jurisdictions that will be most relevant to this study.
- Select up to eight states and five countries for comparison of their current MSW landfill regulations with those from California.
- Review the federal regulations and compare them with those from the selected states, since the states must meet, at a minimum, the federal regulations and many of the individual states include the federal regulations by reference in their regulations.
- Identify those elements that, if applied in California, could possibly improve or enhance California's multimedia regulation of MSW landfills.
- To the extent possible, compare the incremental cost and potential environmental protection benefit of the selected states' and countries' regulations to California's current state of practice.

California is currently enforcing regulations with respect to siting, design, operations, monitoring, post-closure, and landfill gas control, as set forth in Title 27, Division 2 of the California Code of Regulations (27 CCR, Division 2), SWRCB Resolution Number 93-62, the federal "Subtitle D" regulations (also known as Subtitle D of the Resource Conservation and Recovery Act, with regulations found in Title 40, Part 258 of the Code of Federal Regulations [40 CFR, Part 258]), and 40 CFR, Part 60, Subparts Cc and WWW.

The diverse nature of California's geology, hydrogeology, and climate sets it apart from most other states with respect to evaluating regulations that can be most effective in providing environmental protection. When comparing California to most of the eight selected states, regulations that may have been developed for a more homogenous environment may only be applicable to portions of California. In general, California regulations allow for the diversity of the state in all the factors considered for design, and for that reason are likely to provide the most environmentally protective and cost-effective disposal for the people of California.

In comparison to the five countries reviewed, California's regulations appear to be similar in that they all attempt to accommodate highly variable site conditions across the governed area. However, in some instances these countries' regulations tend to be more prescriptive than California's, either by including additional requirements (such as for waste pre-processing) or by

defining a range of minimum requirements to accommodate varying conditions across the country (such as having a tiered structure for defining minimum requirements based on site conditions).

Several regulatory requirements from the other eight states and five countries are believed to have considerable potential for successful implementation in California if it can be shown that they would achieve greater environmental protection than current regulations. These regulatory requirements are:

- Definition of multiple minimum base liner requirements based on site-specific conditions such as landfill size, climate, population density, subsurface conditions, and proximity to groundwater source. However, additional research would be required to appropriately define the tiers and the associated minimum base-liner requirements for each tier.
- Development of a standard for the evaluation of the end of the post-closure care period based on environmental performance. Additional research would be required to develop an appropriate standard for evaluating the future potential for a landfill to "pose a threat" prior to the incorporation of a new regulation in California.

Requirements for the pre-processing and/or pre-treatment of waste prior to disposal to increase the recovery of reusable materials and reduce the volume entering the landfill have been implemented in the European Union (EU). Regulations requiring pre-processing or pre-treatment may be appropriate in California, but would need to be considered along with current requirements and associated costs and benefits prior to the implementation of a new regulation in California.

In addition, three regulatory requirements were identified that may also be applicable, but for which additional research would be needed to evaluate the actual environmental impact of existing landfills that comply with California's current regulations to see if the changes listed below are warranted. These are:

- A siting requirement specifying minimum distance from wetlands.
- A siting requirement specifying proximity to water supply wells based on site-specific conditions.
- A performance requirement for landfill gas control allowing more stringent requirements for the concentration of explosive gases at the landfill boundary that is based on the need for additional protection of human health and the environment.

Further discussion of the basis for all these recommendations is provided in Section 6, along with the basis for exclusion of other selected regulations not recommended for application in California.

2 Introduction

This report presents the results of work completed by GeoSyntec Consultants (GeoSyntec) under Task 6 of the Landfill Facility Compliance Study for the California Integrated Waste Management Board (CIWMB), contract number IWM-C9047. In accordance with the contract scope of work, Task 6 is comprised of the following activities:

- Review current MSW landfill regulations from all 50 states and selected countries to identify those jurisdictions that will be most relevant to this study.
- Select up to eight states and five countries for comparison of their current MSW landfill regulations with those from California.
- Review the federal regulations and compare them with those from the selected states, since the states must meet, at a minimum, the federal regulations and many of the individual states include the federal regulations by reference in their regulations.
- Identifying those elements that, if applied in California, could possibly improve or enhance California's multimedia regulation of MSW landfills.
- To the extent possible, compare the incremental cost and potential environmental protection benefits of the selected states' and countries' regulations to California's current state of practice.

2.1 Organization of This Report

The review of the current MSW landfill regulations from all 50 U.S. states and selected countries to identify jurisdictions for the comparative study is discussed in Section 2.2. The comparison of current MSW landfill regulations from the eight selected states is presented in Section 3. The comparison of current MSW landfill regulations from the five selected countries is presented in Section 4. Discussions regarding regulations that could possibly improve/enhance California's regulations, and the associated incremental costs and benefits, are presented in Section 5. Conclusions and recommendations are provided in Section 6. References used in this part of the study are listed in Section 7. All of the tables referenced in this report are included at the end of the document.

2.2 Basis for Selection of States and Countries

At the beginning of the Landfill Facility Compliance Study, GeoSyntec reviewed summaries of MSW landfill regulations from all 50 U.S. states and several countries to identify those jurisdictions whose regulations were appropriate for comparison to California's current regulations. The primary criteria for selection was that those regulations (1) included elements that differed from California's regulations, and (2) if applied in California, could potentially improve/enhance the current California multimedia regulations. Other criteria included accessibility of the regulations and distribution of social, political, and geographical characteristics pertaining to the landfill or its location.

The primary sources of information for performing this review were the following:

- A technical report for the U.S. Environmental Protection Agency (U.S. EPA) on assessment and recommendations for improving the performance of waste containment systems prepared by authors associated with the Geosynthetics Research Institute (GRI), the University of Illinois, and GeoSyntec Consultants [U.S. EPA, 2002].
- A survey of MSW landfill liner and cover regulations for all U.S. states and selected foreign countries compiled by the GRI [Koerner et al., 1998; Koerner and Koerner, 1999].

- Technical papers published in various landfill conferences and symposia proceedings (specific papers utilized in this study are referenced in appropriate sections).
- Input from the cross-media landfill study team, which was created in keeping with the study's purpose of looking across all environmental media. The team consisted of representatives from the CIWMB, the State Water Resources Control Board (SWRCB), and the California Air Resources Board (CARB).
- Technical knowledge of GeoSyntec, based on landfill practice in most U.S. states and several foreign countries, supplemented by regulatory documents and summaries available from GeoSyntec's in-house library and from Internet websites of various regulatory agencies.

Based on GeoSyntec's review, eight states were identified for inclusion in the comparative study for the following reasons:

- **Delaware:** The regulations provide alternative base liner systems, depending on possible site-specific conditions.
- **New Jersey:** The regulations provide alternative final cover systems, depending on possible site-specific conditions.
- **New Mexico:** The regulations account for the climate conditions in the state, which may be applicable to southern California and other arid areas of California.
- **New York:** The regulations require MSW landfills to have a double composite base liner system, with the two liners separated by a secondary leachate collection and removal system (LCRS), which is also called a leak detection system (LDS).
- **Pennsylvania:** The regulations require consideration of alternatives for post-closure land use.
- **Washington:** The regulations allow landfills in arid regions to be designed on a performance basis that could result in the landfill being designed with no base liner as long as the maximum concentration of contaminants are below regulatory levels.
- **West Virginia**: The regulations provide alternative final cover systems, depending on possible site-specific conditions.
- **Wisconsin**: The regulations provide for state-approved alternatives to the prescriptive base liner system.

Based on GeoSyntec's review, five countries were identified for inclusion in the comparative study for the following reasons:

- **Australia:** The regulations provide for all MSW to be pre-treated starting in 2004.
- **Brazil:** Provides broad geographical coverage as a representative of South America.
- **European Union (EU):** Although the EU is a union of several countries, it is treated as one entity for the purposes of this report, with two countries (Germany and the United Kingdom [U.K.]) examined in particular. Some country-specific regulations (such as Germany's) require mechanical pretreatment of waste.
- **Japan:** Provides broad geographical coverage as a representative of Asia, economic comparison as the second largest economy in the world, and brings innovative approaches to waste management. Japan has a high population density (as does California), a climate similar to the climate in parts of California, and seismic conditions similar to California's.

- **Republic of South Africa:** Newly adopted landfill regulations are performance-based.

2.3 Glossary

The following terms are used throughout the body of this report. For purposes of this report, these terms have the following meanings:

Anaerobic digestion: reduction of the waste mass prior to disposal by biochemical processes (for example, growth of bacteria) that occur in the absence of oxygen.

Biogases: gases generated by a waste mass through biological reactions in the waste mass; in conjunction with a landfill, biogases may be referred to as landfill gas (LFG).

Composting: reduction of the waste mass prior to disposal by biochemical processes (for example, growth of bacteria) that occur in the presence of oxygen.

Dispersion: transport and distribution of a mass through a medium by various means, including convection and diffusion.

Double composite liner system: landfill base containment system consisting of two single composite liners with a secondary leachate collection and removal system (also called a leak detection system) between the liners.

Double liner system: landfill base containment consisting of two liner systems (none of which must be a composite liner) with a secondary leachate collection and removal system (also called a leak detection system) between the liners.

Emissions: uncontrolled discharges of liquid, gas, or solid particles from a landfill to air, water, or land.

Evapotranspiration: the evaporation and transpiration processes of vegetation planted on the ground surface that can minimize the infiltration of water through soil.

Fly ash: all solids, including ash, charred papers, cinders, dusty soot, or other matter that rise with the hot gases from combustion rather than falling with the bottom ash.

Greenhouse gas: any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halogenated fluorocarbons (HCFC), ozone (O_3), perfluorinated carbons (PFC), and hydrofluorocarbons (HFC).

Head: pressure exerted by a column of liquid.

Landfill gas: a product of the anaerobic microbial decomposition of organic waste, consisting principally of approximately 50 percent methane, 50 percent carbon dioxide, and typically less than 5 percent nonmethane organic compounds.

Leak detection system: also called the secondary leachate collection and removal system (LCRS); a relatively high-permeability component of the landfill base containment system situated below the primary liner for the collection and removal of liquids (leachate) generated by the waste mass in the event that they percolate through the primary liner.

Leachate collection and removal system (LCRS): a relatively high-permeability component of the landfill base containment system situated above the primary liner for the collection and removal of liquids (leachate) generated by the waste mass. Also referred to as the primary LCRS in the case of single liners.

Mechanically-biologically processed (MBP) waste: the residual waste remaining after mechanical separation and biological pre-treatment have been performed.

Natural geologic liner: Landfill base containment consisting of native subsurface materials. These materials may be reworked during construction or left undisturbed.

Performance-based regulation/requirement: a regulation or requirement defined with the intent to meet a particular performance criterion (for example, a requirement to design a geosynthetic component to "survive tensile loading" [instead of to meet defined minimum thickness requirements] would be a performance-based requirement).

Prescriptive regulation/requirement: a regulation or requirement in which the specifics for how a component is to be constructed are defined (for example, a requirement for a single composite liner system consisting of a compacted clay liner (CCL) and a geomembrane liner with defined minimum thickness and hydraulic conductivity [as opposed to meeting a performance component as indicated in the above definition] would be a prescriptive requirement).

Pyrolysis: the thermal degradation of waste under controlled conditions at high temperatures in the absence of oxygen.

Residual waste: the solid materials remaining after the separation of waste or the completion of a chemical or physical process, such as digestion.

Single clay liner: landfill base containment system consisting of a compacted soil layer, usually with a requirement for minimum thickness and maximum allowable hydraulic conductivity.

Single composite liner: landfill base containment consisting of a synthetic membrane barrier overlying a compacted clay liner (CCL). The CCL usually includes a requirement for minimum thickness and maximum allowable hydraulic conductivity.

Sole source aquifer: an aquifer (designated by the U.S. EPA pursuant to section1424e of the Safe Drinking Water Act [Public Law No. 93-523]) which is the sole or principal drinking water source for an area and which, if contaminated, would create a significant hazard to public health.

Waste stabilization: the reduction in biological, chemical, and physical reactions in the waste mass with time, caused by the depletion of the sources for these reactions. The degradation of organic matter, leaching of chemical constituents, and settling of the waste mass (resulting in reduction in void space) are examples of biological, chemical, and physical components of waste stabilization.

3 Comparison of Current MSW Regulations From the U.S. Government, Eight States, and California

The following U.S. states were selected for comparison of current MSW regulations with those from California:

- Delaware
- New Jersey
- New Mexico
- New York
- Pennsylvania
- Washington
- West Virginia
- Wisconsin

Federal regulations from Title 40, Part 258 of the Code of Federal Regulations (40 CFR, Part 258) were included in the comparison tables to allow the reader to assess if a given state regulation was more stringent than the corresponding federal regulation. Regulations in 40CFR258 were promulgated in 1991 under the authority of Subtitle D of the Resource Conservation and Recovery Act (RCRA). RCRA was passed by Congress in 1976 and amended in 1984, and the 40 CFR, Part 258 regulations were promulgated in response to the 1984 amendment. Thus, for the purposes of this document, the federal regulations are referred to at times as "Subtitle D" regulations.

Each of the eight states has unique elements in its current regulations. The contractor for the study hypothesized that California's regulations could be improved or enhanced if some of these elements were adopted in California. These unique elements are described in Section 2.2.

In most cases, the regulations were downloaded from Internet websites of the appropriate regulatory agencies in different states. Table 1, included at the back of the report, contains the names of the state agencies responsible for regulating MSW landfills in each state, their Internet website addresses, and the name of the current MSW regulations.

3.1 Status of States' Current MSW Regulations

This section provides a brief overview of each state's current MSW regulations and current state of practice. The information presented here was obtained from Internet websites of regulatory agencies.

3.1.1 California

California is geographically large with a large population. California has 158 active MSW landfills[*] to serve its large and widespread population. More than half of the MSW disposed of in California is disposed of at publicly owned sites. The remainder is disposed of in privately owned sites. A complete discussion of the diversity of California's MSW landfills is presented in the Landfill Facility Compliance Study Phase I report [GeoSyntec, 2003].

Regulation of California's MSW landfills is the responsibility of several regulatory bodies, including the CIWMB, and State Water Resources Control Board (SWRCB) which promulgates water quality protection regulations, the 9 regional water quality control boards (RWQCB) which apply the SWRCB's regulations, and the 35 local air quality management districts (AQMD) and air pollution

[*] Between 1998 and 2001 when the data for the cross media inventory was collected, there were 158 active MSW landfills in California. Since that time some landfills may have closed., thus reducing the total number of active sites.

control districts (APCD). California is currently enforcing regulations with respect to siting, design, operations, monitoring, post-closure, and landfill gas control, as set forth in the California Code of Regulations[†] (CCR) (Title 27 [27 CCR], Division 2), SWRCB Resolution Number 93–62, the federal Subtitle D regulations (40 CFR, Part 258), and 40 CFR, Part 60, Subparts Cc and WWW.

The promulgation of the regulations in 27 CCR, Division 2 is divided between the CIWMB and the SWRCB. At the local level, enforcement agencies (EA) enforce CIWMB regulations and RWQCBs enforce SWRCB regulations.

In California, the 35 local AQMDs and APCDs have primary authority to regulate emissions from MSW landfills. Each district is responsible for developing and enforcing air quality regulations within its district. The Air Resources Board (ARB) provides technical support to the districts and oversees local district compliance with State and federal law. A complete discussion of California's regulatory requirements can be found in the Landfill Facility Compliance Study Task 1 report [GeoSyntec, 2002].

The SWRCB classifies waste management units based on their ability to contain MSW under 27 CCR. With respect to certain construction standards for seismic design and storm design, the SWRCB differentiates between Class II and Class III units. For ease of comparison with other states that do not sub-divide MSW regulations in this manner, this report considers SWRCB requirements only for Class III facilities. All other California landfill regulations presented herein apply to both Class II and Class III units.

3.1.2 Delaware

Delaware is relatively small both in geographic area and population, with a small number of MSW landfills. The Delaware Code of Environmental Laws (Title 7) governs solid waste disposal and related practices.

3.1.3 New Jersey

New Jersey is small in geographic area and has a limited number of MSW landfills. According to the New Jersey Department of Environmental Protection website [site accessed November 2003], there are 13 operating landfills in the state. New Jersey regulates solid waste disposal activities as a public utility, generally discouraging private development of new MSW landfill capacity.

3.1.4 New Mexico

New Mexico is relatively large in geographic area, but small in population. Consequently, it has a small number of MSW landfills. The New Mexico Statutory Authority, Title 20, Chapter 9 governs the handling and disposal of solid waste.

3.1.5 New York

New York is a heavily populated state with numerous MSW landfills to support its large population. Part 360, Chapter IV of the New York Code of Rules and Regulations (NYCRR) governs the general siting, design, and operating requirements of MSW landfills.

3.1.6 Pennsylvania

Pennsylvania has a moderately large population and a correspondingly high population density. Pennsylvania has 51 operating municipal landfills, both privately and publicly owned. The regulation

[†] GeoSyntec's source for information on Title 27 of the California Code of Regulations was the regulatory text submitted by the CIWMB and approved by the Office of Administrative Law on June 18, 1997: "Combined SWRCB/CIWMB Regulations, Division 2, Title 27."

of MSW landfills falls under the jurisdiction of the Pennsylvania Department of Environmental Protection.

3.1.7 Washington

Washington has a moderate population count (approximately 5 million people), with 19 landfills accepting MSW. Most of these are publicly owned, though there are a few privately owned sites. Solid waste disposal is governed by the Department of Ecology under the Washington Administrative Code (WAC).

3.1.8 West Virginia

West Virginia is a medium-sized state with a relatively low population density. There are 18 landfills, half of which are publicly owned and half of which are privately owned. The disposal of solid waste is regulated by the West Virginia Department of Environmental Protection.

3.1.9 Wisconsin

The population and size of Wisconsin is comparable to that of Washington. However, there are 73 licensed landfills in Wisconsin, compared to Washington's 19. Landfill location, performance, design, and construction criteria are covered under Chapter N504 of the Wisconsin Department of Natural Resources regulations.

3.2 Summary of MSW Regulations

Table 2 is a summary table listing the regulatory topics presented for state regulations. The comparisons of various regulations in the eight states against those from California cover important aspects of MSW landfill siting, design, operation, and performance, and are in Tables 3–10. Federal regulations, where applicable, are also provided. The items covered include:

- Siting (Tables 3a, 3b and 3c).
- General design requirements (Tables 4a and 4b).
- Base liner system configuration (Tables 5a through 5d).
- Leachate collection and removal system configuration (Tables 6a and 6b).
- Provisions for leachate recirculation (Table 6c).
- Final cover system configuration (Tables 7a through 7c).
- Post-closure maintenance requirements (Table 8).
- Groundwater monitoring regulations (Table 9).
- Landfill gas control regulations (Table 10).

The information for the states was obtained directly from the most current state MSW regulations available at the time the report was written.

Key features of the regulations found during the review are summarized in this section. The discussions are grouped by topic and parallel the organization of the tables.

3.2.1 Siting

The specific elements of siting criteria covered in the comparison are:

- Separation between waste and highest groundwater.
- Type of geologic material underlying the waste unit (subgrade).
- Separation between top of bedrock and bottom of liner.
- Distance from floodplain, wetlands, water supply wells, and aquifer.
- Location with respect to airports.

Separation Between Waste and Highest Groundwater

Table 3a presents a comparison of current regulations regarding separation between waste and highest anticipated groundwater. While federal regulations do not address this issue, current regulations in the eight states and California all have some requirement for a minimum separation between the waste and highest anticipated groundwater. The separation varies from 4 feet (for seasonal high groundwater in West Virginia) to 100 feet in New Mexico. California's requirement of 5 feet is consistent with the requirements in three other states. Regulations in seven of the eight states and California allow for alternatives to the required minimum separation. The two states that do not allow for alternatives are New Mexico and Pennsylvania.

Type of Geologic Material Underlying the Waste Unit

Table 3b presents a comparison of current regulations regarding material underlying the waste unit. Two states have requirements related to siting landfills immediately above bedrock (New Jersey) or an unconsolidated deposit that is either natural or constructed to be at least 20 feet thick (New York), and two states have requirements for an engineered sub-base (Pennsylvania, West Virginia). An unconsolidated deposit is a sediment that is loosely arranged or unstratified, or that has particles which are not cemented together, found either at the surface or at depth. Neither California, the remaining states, nor federal regulations have such requirements in the current regulations.

Separation Between Top of Bedrock and Bottom of Liner

Table 3b presents a comparison of current regulations regarding separation between bedrock and the bottom of the liner. Three states have minimum required separation between the bedrock surface and bottom of liner (New York, West Virginia, Wisconsin). A fourth requires double containment liner when bedrock is at or near the ground surface (New Jersey). Neither California, the remaining states, nor federal regulations have any such requirements in the current regulations.

Distance From Floodplains, Wetlands, Water Supply Wells, and Aquifers

Table 3c presents comparisons of current regulations regarding distance of the landfill from a floodplain, wetlands, water supply wells, and aquifers.

Distance From Floodplain: Four states require that landfills not be located within a floodplain (Delaware, New Mexico, Pennsylvania, Wisconsin). The remaining states have the same requirement as Subtitle D (40 CFR, Part 258, section 11), which requires that landfill units located within a 100-year floodplain must demonstrate that the unit will not restrict the flow of the 100-year flood, reduce temporary water storage capacity, or result in washout of solid waste. California's regulations include the federal requirement by reference.

Distance From Wetlands: Three states do not allow landfills to be located within 100 feet to 500 feet (distance varies between the three states) of wetlands (New Mexico, Pennsylvania, West Virginia). The remaining states have the same requirement as Subtitle D (40 CFR, Part 258, section 12), which requires that landfills not be located in wetlands unless it is demonstrated that the construction of the landfill will not have an adverse effect. California includes the federal requirement by reference.

Distance From Water Supply Wells: Six states have restrictions on location of a landfill with respect to water supply wells. The minimum allowable distance varies from 300 feet if the landfill is downgradient of a water source, to ¼-mile if the landfill is upgradient of a water source (both in Pennsylvania). The remaining of the eight states (New Jersey and New York), California, and federal regulations do not have any restriction.

Distance From Aquifers: Two states specifically require that landfills not be constructed immediately above primary water supply or sole-source aquifers (New York and Washington). The remaining states, California, and federal regulations do not have any such restriction.

Location With Respect to Airports

Table 3c presents a comparison of current regulations regarding landfill siting with respect to local airports. Consistent with the federal regulations, the eight states and California require a minimum allowable distance from airport runways based on aircraft type. However, some states have additional requirements, including a maximum landfill relief requirement in New York and restrictions based on runway length in New Jersey.

3.2.2 General Design Requirements

Tables 4a and 4b compare miscellaneous design requirements of the different states. Table 4a presents the general design requirements. Typical general design requirements may include a checklist of design elements, a geotechnical report, a geologic map, liner stress analyses, hydrologic calculations, and gas system design. Table 4b presents requirements specific to liner performance evaluations and surface water and stability issues. Typical specific requirements include the design storm, static factor of safety for slope stability, and the design earthquake.

Existing California regulations require the submittal of a report of waste discharge (ROWD) and a report of disposal site information (RDSI) for a landfill, which must present various design parameters for the site. Some of these design parameters are included in Table 4a as a comparison to design requirements of other states.

3.2.3 Base Liner System

Table 5a presents a comparison of current regulations regarding permitted base liner types. The federal Subtitle D regulations (40 CFR, Part 258, section 40) require that, at a minimum, in all states new waste units must either install a single composite base liner or demonstrate that groundwater quality performance criteria are met for an alternative base liner system. The following liner types are permitted, according to the regulations reviewed. Since some state regulations permit more than one type of liner in the same state, the sum of the number of states for all liner types will be greater than the total number of states reviewed.

- Natural geologic/single clay liner (Delaware, New Jersey, Washington, Wisconsin).
- Single composite liner (six states plus California, not including Pennsylvania and New York).
- Double composite liner (New Jersey, New York).
- Double liner, but not double composite liner (Delaware, Pennsylvania).

Details for each liner type are presented in Tables 5b through 5d. A summary discussion of each liner type is presented in the following sections.

Natural Geologic/Single Clay Liner

Table 5b presents details on this liner type. Four states allow either a natural geologic material, a clay liner, or no liner, provided certain conditions are satisfied. California does not allow natural geologic liners or single clay liners unless the site is specifically exempt from Subtitle D requirements as described in Section 5.2.3. Delaware and New Jersey permit natural geologic material to be considered as the liner for landfills in areas where either underlying groundwater is not used (Delaware) or where there is a stable low-permeability geologic formation with low hydraulic conductivity (New Jersey). The required thickness and hydraulic conductivity for the natural formation are specified in the regulations and are presented in Table 5b. Washington regulations permit landfills to be constructed without any liner in arid areas (defined as areas with annual precipitation of less than 12 inches), provided contaminant levels specified in the regulations are not exceeded in the hydrostratigraphic units identified for the specific landfill. Delaware and Wisconsin permit single clay liners that are 5 feet thick with a hydraulic conductivity no greater than 1×10^{-7} centimeters/second (cm/sec). New Jersey allows single clay liners that are 3 feet thick with a hydraulic conductivity no greater than 1×10^{-7} cm/sec.

Single Composite Liner

Table 5c presents details on this liner type. California, New Mexico, and West Virginia have the same requirement as Subtitle D (40 CFR, Part 258, section 40), with varying requirements for minimum thickness of the geomembrane component. Delaware, New Jersey, Washington, and Wisconsin permit natural geologic or single clay liners in addition to single composite liners. All states permitting single composite liners follow the same requirements as Subtitle D (40 CFR, Part 258, section 40) with respect to minimum thickness and hydraulic conductivity, except Wisconsin, which requires the compacted clay liner (CCL) to be 4 feet thick (as compared to the Subtitle D required thickness of 2 feet). These states all require the maximum saturated hydraulic conductivity of the CCL to be 1×10^{-7} centimeters/second. California and Washington allow for alternatives provided it can be successfully demonstrated that the environment is equally protected (compared to the use of prescriptive liner) and that the prescriptive standard is burdensome.

Double Composite Liner

For the purposes of this study, a double composite liner system is generally defined as two composite liners separated by a secondary leachate collection and removal system (also called a leak detection system). Details on this liner type are presented in Table 5d. Two states (New York and New Jersey) require double composite liners. New Jersey requires a double composite liner only when bedrock is at or near the ground surface and serves as direct source of public community water system. Landfills in New Jersey not using a double composite liner are required to make a performance evaluation of the landfill in the geologic formation using a three-dimensional mass transport model. New York requires a double composite liner on the floor areas (with slopes less than or equal to 25 percent) and a geomembrane primary liner with a composite secondary liner on the side-slope areas (with slopes greater than 25 percent). In each case, the regulations require a secondary leachate collection and removal system (leak detection system) to be installed between the primary and secondary liners. California has no existing regulations requiring a double liner system, but allows permitting agencies to require one.

Double Liner

For the purposes of this study, a double liner system is generally defined as two liners (a composite liner over a single liner) separated by a secondary leachate collection and removal system (leak detection system). Details on this liner type are presented in Table 5d. One state, Delaware, requires a double liner when the landfill is underlain by an aquifer that is an expected source of water supply

and/or capable of significant contaminant transport to adjacent surface waters. The double liner consists of a composite primary liner (consisting of a geomembrane with either a compacted clay liner or a geosynthetic clay liner) and a single secondary liner consisting of either a geosynthetic or a compacted clay liner. Pennsylvania requires only that one of the two liners be composite (either composite primary and single secondary liners, or single primary and composite secondary liners). "Single" in this case refers to either a geosynthetic or a compacted clay layer. A secondary leachate collection and removal system (leak detection system) is required to be installed between the primary and the secondary liners. California has no existing regulations requiring a double liner system, but allows permitting agencies to require one.

Liner Design and Construction

Regulations in several states include specific requirements that relate to design, construction, and construction quality assurance issues. These issues are presented in Tables 5c and 5d in connection with single composite and double composite liners, respectively. A few of the key points are discussed below.

- Regulations in California and New Jersey have requirements for minimum construction and testing for clay and geosynthetics.
- Regulations in West Virginia and Wisconsin include guidance for orientation of field seams of geosynthetics.
- Regulations in Wisconsin specify the minimum number of vehicle loads permitted over 1 foot and 2 feet of soil placed over a geomembrane.
- Regulations in West Virginia and New Jersey specify the dimension of anchor trenches.
- Regulations in Wisconsin require anchor trenches to be designed.
- Regulations in New Mexico, New York, and West Virginia require designs to include calculation for tensile forces in geosynthetics (only for slopes steeper than 25 percent, in the case of New Mexico and West Virginia).
- Regulations in Wisconsin require adjacent liners with clay component to be keyed together. The regulations also specify soil properties of material appropriate for use as clay liner.

Federal and California regulations do not include such specific requirements.

3.2.4 Leachate Collection and Removal System (LCRS)

Tables 6a–6c present summaries of current regulations regarding primary and secondary LCRSs.

Regulations regarding the primary LCRS (in the case of single liners) and secondary LCRS (also called the leak detection system [LDS]) (in the case of double liners) are presented in Tables 6a and 6b. The thickness of the primary and secondary LCRSs is not specified in California, New Mexico, and Washington, as well as in federal Subtitle D regulations. Where specified, the thickness varies from 1 foot (in Delaware and Wisconsin) to 2 feet (in New York). The hydraulic conductivity of the primary and secondary LCRSs is not specified in California, New Mexico, and Washington, nor in federal Subtitle D regulations. Where specified, in most cases the minimum allowable saturated hydraulic conductivity is 1×10^{-2} centimeters/second, except in West Virginia, which allows a minimum saturated hydraulic conductivity of 1×10^{-3} centimeters/second.

Most states have requirements with respect to the design flow for the primary LCRS. Only California has the requirement to design the LCRS to remove twice the maximum anticipated daily volume of

leachate. New York requires that the LCRS remove the peak flow from the 24-hour, 25-year storm event within seven days based on the initial start-up condition, with no waste in place. New Mexico specifically excludes storm events from LCRS design calculations.

Of the eight states reviewed, all eight have LCRS design specifications that are equivalent to the federal Subtitle D requirement for less than 30 centimeters of head build-up on the base liner. California has a more restrictive regulation that incorporates the federal maximum of less than 30 centimeters by reference and also requires no build-up of hydraulic head on the liner (except in the sump where the minimum allowable head for efficient pump operation is allowed).

Regulations in six states specify a minimum slope of the primary and secondary LCRSs of 2 percent, five states specify minimum pipe diameter (most commonly 6 inches), and four states specify pipe type (most commonly schedule 80 or greater). Current California regulations do not specify requirements for any of the above features.

Secondary LCRSs (LDSs) are required in those states that require either double composite or double liner, specifically Delaware, New Jersey, New York, and Pennsylvania. In addition, West Virginia requires landfills to have a 1-foot thick LDS underneath single composite liners. Comparisons of LDS requirements are presented in Table 6b. California regulations do not require installation of an LDS, but allow regulatory agencies to require one.

3.2.5 Leachate Recirculation

Table 6c presents discussions regarding leachate recirculation regulations. Of the state regulations reviewed, all except one (New Mexico) address leachate recirculation through specific requirements. All of these states required either a composite liner or double liner in the landfill units where leachate recirculation is done. Several states, including California, require the landfill unit into which leachate is being recirculated to have sufficient capacity to absorb the leachate.

3.2.6 Landfill Closure (Final Cover System)

Landfill closure incorporates various activities, including, but not limited to, design and construction of the gas collection system, final cover system, and surface water drainage system. Gas collection and other components of landfill gas control are discussed in Section 3.2.9 and are summarized in Table 10. Surface water drainage is discussed with the general design requirements in Section 3.2.2 and is presented in Tables 4a and 4b. Discussions of regulations related to final cover systems are discussed in this section and are presented in Tables 7a–7c.

Three states (New York, Washington, and Wisconsin) require the final cover system to be composite, consisting of a geomembrane and a low-permeability soil layer, under certain conditions. California and the remaining five states do not require a composite final cover. The thickness and hydraulic conductivity of the final cover components are presented in Table 7b. Most states, including California, have requirements in their regulations for minimum and maximum slopes on the final cover system. California and three other states (New York, Pennsylvania, and West Virginia) have requirements for benches or terraces on slopes. Three states (New Jersey, New York, and West Virginia) have requirements for inclusion of gas venting layer. Four states (New Jersey, Pennsylvania, West Virginia, and Wisconsin) require a drainage layer in the final cover system. California does not have requirements for either a gas venting layer or a drainage layer.

3.2.7 Post-Closure Requirements

Post-closure requirements of different states are compared in Table 8. Five states employ the minimum closure period of 30 years. California requires a minimum 30-year post-closure maintenance period (to be extended as long as wastes pose a threat to groundwater quality, public health and safety, and the

environment). Wisconsin employs a 40-year minimum post-closure period. The length of the post-closure period is not defined in New Mexico. Additional criteria in Table 8 include requirements for reporting, operations and maintenance, monitoring, financial assurance, and land use restrictions.

3.2.8 Groundwater Monitoring Regulations

Table 9 summarizes groundwater monitoring regulations of the eight selected states and California (and federal regulations). The groundwater monitoring regulations discussed in this report consider the applicability of groundwater monitoring requirements, required programs, water standards, concentration limits, standards for defining each landfill's point of compliance, compliance periods, system requirements, and the details of various stages for monitoring. The groundwater monitoring programs for the eight selected states and California are similar in that they generally follow the federal requirements, though there are some differences among the programs.

California allows a concentration limit of background or a concentration limit of greater than background (CLGB). Wisconsin's definition is similar to California's. Six of the eight states define allowable concentration limits for groundwater contaminants using criteria similar to the federal regulations—that is, the maximum contaminant level (MCL), background, or health-based limits, as appropriate. New Mexico differs from the other seven states and California, in that it defines different allowable concentrations depending on whether the site is in detection monitoring or assessment monitoring.

Six of the eight states and California have requirements similar to the federal regulations for evaluating the number of wells required in the groundwater monitoring system. These states (and federal regulations) require a sufficient number of wells to adequately monitor groundwater quality. Only Pennsylvania and West Virginia specify a minimum number of allowable wells.

The eight states, California, and the federal regulations all define slightly different requirements for responding to corrective action. However, the Wisconsin regulations are the most significantly different in that they define a range of possible corrective actions that may be required, depending on the severity of the groundwater impact at the site.

3.2.9 Landfill Gas Control Regulations

Table 10 summarizes air and explosive gas regulations applicable to landfills in different states.

Federal regulations related to air quality that apply to MSW landfills are listed 40 CFR, Part 60, Subparts Cc and WWW. These regulations are prohibitory/source-specific and include emission control, emission limits, monitoring, testing, record keeping, and reporting requirements.

California is divided into 35 AQMDs or APCDs. Each district is responsible for developing and enforcing air quality rules within its district. These rules may vary slightly due to the areas they are in being classified as attainment or non-attainment zones for ozone. The majority of these rules were adopted to implement the federal requirements for "new" and "existing" larger MSW landfills. Some district landfill rules also apply to smaller landfills in an effort to obtain further VOC emission reductions. Because the breadth of the regulations varies from district to district, two districts representing less restrictive (Shasta County) and more restrictive (South Coast) regulations are presented in this report. The AQMD/APCD regulations are classified as either prohibitory/source-specific or permitting regulations. While several types of air quality regulations are applicable to MSW landfill, including regulation of ancillary equipment such as turbines and internal combustion reciprocating engines, only regulations specific to the regulation of landfills will be discussed in this report.

The regulations provided from the eight states were collected primarily from the landfill regulations for that state. More detailed specifics of the air quality regulations for individual states may be available in regulations included by reference in that states' landfill regulations, but they were not necessarily reviewed in conjunction with preparation of this report.

In many cases, the issues addressed in the federal air quality regulations are not defined in the states' regulations. Irrespective of these cases, many of the states' air quality regulations replicate the federal requirements, with some variations.

Of the eight states reviewed, only New York has landfill size criteria for defining applicability, similar to Shasta County in California.

New Mexico, Washington, and Wisconsin are the only states that do not require some form of compliance plan be submitted to define the methods for meeting air quality requirements.

Seven states, the federal regulations, and California specify maximum explosive gas concentrations at the site boundary of between 5 percent and 100 percent of the lower explosive limit (LEL). Wisconsin is the most restrictive in that 0 percent LEL of combustible gases may be required at the landfill boundary.

Monitoring, testing, record-keeping and requirements tend to vary from state to state.

4 Comparison of Current MSW Regulations From Five Countries With California Regulations

The following countries were selected for comparison of current MSW regulations with those from California:

- Australia.
- Brazil.
- European Union (EU).
- Japan.
- Republic of South Africa.

Each of the five countries was selected either because of unique elements in its current regulations that differed from California's, because of climatic conditions similar to California's, or to provide socio-economic and geographic diversity (as in the case of Brazil). It was hypothesized that the regulations in California could potentially be improved or enhanced by applying some of the features from these regulations. The basis for selecting these individual countries is described in Section 2.2.

In most cases, the regulations were either downloaded from websites of the appropriate regulatory agencies in different countries or from information provided by technical experts contacted in each country. Table 11 contains the names of the agencies responsible for regulating MSW landfills in each country (and California), their website addresses, and the name of the current MSW regulation, if available.

4.1 Status of Countries' Current MSW Regulations

This section provides a brief overview of each country's current MSW regulations and current state of practice. The information presented here was obtained from published technical literature, websites of regulatory agencies, and international experts advising GeoSyntec on this project.

4.1.1 Australia

In Australia, MSW landfills are regulated at the state level, and the current practice is state-specific [GRI, 1999]. The development of MSW regulations and practice is influenced by variations in geology and hydrogeology across Australia [Bouazza and Parker, 1998]. Since no country-wide standard of practice is available for Australia, for the purposes of this project two states—New South Wales and Victoria—were selected as representative examples of current MSW landfill regulations and standard of practice in Australia. Generally, more specific topics are addressed in Victoria's regulations than in New South Wales, so for many topics only Victoria's regulations are presented.

4.1.2 Brazil

The current MSW landfill regulations in Brazil were developed by the Brazilian Association of Technical Standards (ABNT) and updates to the regulations are currently under development [GRI, 1999]. While national guidelines exist, some of the standards vary from state to state.

4.1.3 European Union

The main EU regulation pertaining to MSW landfills is the EU's Landfill Directive adopted in 1999. The Directive sets a timetable for the implementation of various actions that relate to design, construction, operation, closure, and post-closure care of landfills. The EU member states were required to adopt the requirements of the Landfill Directive into their national regulations by 16 July 2001 [Laraia, 1999; Wagner, 2001]. While the Directive is prescriptive in certain aspects, there are many areas that are at the discretion of the regulatory authorities of each individual member state. Consequently, there will be room for considerable variations in landfill regulations and standards between member states even when the Directive has been fully implemented.

For the purpose of this project, GeoSyntec utilized the standards adopted in the EU's Landfill Directive as a source for current regulations in the EU. However, in order to obtain an understanding of the current state of practice in EU member states, GeoSyntec contacted prominent landfill experts in Germany and the U.K..

Germany

The current German MSW landfill regulations were prepared in the late 1980s to early 1990s. The regulations are, in general, more stringent than those in the EU Landfill Directive. The EU Landfill Directive will be reflected by the German "Deponie-Verordnung," to be issued by the federal government in the near future. The new German regulations will attempt to maintain the high technical standards of the existing German regulations without contradicting the EU Landfill Directive.

Besides the landfill regulations issued by the German federal government, the German Society for Geotechnical Engineering has prepared extensive Geotechnical Recommendations for Landfills and Contaminated Land. These recommendations were first published in 1991. The fourth edition is currently under development.

United Kingdom

The Environment Agency of the government of the UK provides regulatory guidance with respect to the EU Landfill Directive. This guidance has a strong emphasis on a risk-based approach to landfill design and operations. In areas where the EU Landfill Directive provides opportunity for interpretation of a requirement, the UK provides opportunity to accept changes if the changes can be justified through a technical assessment of the risks to the environment.

4.1.4 Japan

The current MSW regulations in Japan are applied nationwide and appear to be generally performance-based, rather than prescriptive [GRI, 1999]. The regulations and information regarding the structure of waste management regulation are not readily available in English.

4.1.5 Republic of South Africa

Historically, legislation regarding environmental protection and waste management in the Republic of South Africa was fragmented, diverse, and generally ineffectively administered. The most significant new development in the field of environmental protection in South Africa has been the drafting of an integrated waste management strategy aimed for a large part at pulling together all the above legislation. During 1997, the Department of Water Affairs and Forestry (DWAF) and the Department of Environmental Affairs and Tourism (DEAT), along with representation from the environmental departments of all nine provincial governments initiated a project for the development of a National Waste Management Strategy (NWMS) for South Africa. The overall objective of the NWMS is a reduction in the generation of wastes and their associated environmental impacts, thereby ensuring that

the socio-economic development and health of the people of South Africa, as well as the quality of national environmental resources, are not adversely affected by uncontrolled and uncoordinated waste management practices [Wiechers, 1999; Joubert et al, 1999].

The NWMS follows a hierarchy approach and was implemented in stages beginning in late 2000 [Morris, 2001]. The DWAF produced a set of Minimum Requirements Documents governing waste disposal. The most recent edition of this document was published in 1998.

The current MSW landfill regulations in South Africa take into account both the size and type of community being served, and the water balance (whether the site is dry or wet) at a landfill site. MSW landfills are generally divided into four classes based on their daily waste intake. For each class, the climatic water balance is calculated as the numerical difference between rainfall and evaporation. Sites for which water balance is positive (amount of rainfall is greater than evaporation) for less than one year in five for all the years for which data is available, are termed "dry" sites in this report. Sites for which water balance is positive for more than one year in five for all the years for which data is available are termed "wet" sites in this report

4.2 Summary of MSW Regulations

Table 12 is a summary table defining the regulatory topics considered for the various countries. The comparisons of various countries' regulations against those from California are presented in a series of tables covering important aspects of MSW landfill waste handling and pre-processing, siting, design, operation, and performance. The items covered in the tables include:

- Pre-processing and special handling (Table 13).
- Siting (Table 14).
- General design requirements(Table 15).
- Base liner system configuration (Tables 16a–16c).
- LCRS configuration (Table 17).
- Final cover system configuration (Tables 18a–18c).
- Post-closure maintenance requirements (Table 19).
- Landfill gas control regulations (Table 20).

In the tables, each element under comparison is presented in a row, with the various country regulations in different columns.

Most of the information provided in the tables was obtained from a variety of sources. Wherever possible, information was obtained from websites (in English) of the regulatory agencies of the different countries. The remaining information was collected from existing literature, notably GRI [GRI, 1999]. GeoSyntec recognized that data collected in this fashion, especially from secondary literature sources, could potentially have information gaps and errors. This is particularly applicable in the case of countries where the original regulations are not published in English. GeoSyntec contacted recognized experts in the field of MSW practice in each country and requested them to review the collected data and provide any supplementary information. The following experts contributed to this study in this manner:

- Prof. A. Bouazza, Monash University, Victoria, Australia (Australian regulations).
- Prof. Claudio Mahler, University of Sao Paulo, Brazil (Brazilian regulations).

- Dr-Ing. Erwin Gartung, Geotechnical Institute, LGA, Germany (EU regulations).
- Dr. Richard Beaven, University of Southampton, U.K. (EU regulations).
- Prof. Masashi Kamon, University of Kyoto, Japan (Japanese regulations).

In the case of regulations from South Africa, GeoSyntec staff Dr. Jeremy Morris, who completed a doctoral dissertation on MSW landfill design studying in South Africa, reviewed the current regulations and provided input for the tables.

Key features of regulations found during the review are summarized in this section. The discussions are grouped by element of regulation, following the breakdown of the tables.

4.2.1 Pre-Processing and Special Handling

Information regarding the need for pre-processing and special handling is presented in Table 13. Very limited information was obtained regarding the need for pre-processing or special handling of wastes; however, interpretation of the regulations suggests that pre-processing in some manner is required in Australia (Victoria), the EU, and Japan. Current EU regulation requires reduction of biodegradable waste and has a time schedule for reduction. The volume of MSW landfilled must be reduced by 25 percent within five years and by 50 percent within eight years. The weight must be reduced by 65 percent within 15 years of the date specified. Japan requires pre-processing or special handling for some types of waste, but details of this requirement were not available. In Victoria, Australia, a requirement for mechanical pre-processing, in the form of separation, shredding, or baling, is specified in the regulations. Current California regulations do not require pre-processing of waste prior to disposal, other than the shredding of whole tires.

4.2.2 Siting

Discussions on siting elements are presented in Table 14. In many cases, siting criteria are not specified in the regulations of the countries included in the comparison. However, the EU allows for the consideration of site-specific conditions when evaluating a landfill site. Australia, Brazil and South Africa have specific requirements for separation from groundwater of 2 to 3 meters. Australia and South Africa have specific requirements for siting within a floodplain or wetlands. California regulations include specific requirements for separation from groundwater. These regulations and the federal regulations address proximity to floodplains, wetlands, and airports.

4.2.3 General Design Requirements

Comparison of current regulations regarding design requirements is presented in Table 15. Limited amount of information was available regarding design requirements. However, South Africa does specify design for a 50-year, 24-hour design storm. California requires that surface water systems at Class III MSW landfills be designed to control a 100-year, 24-hour storm. Slope stability analyses are required in Brazil, the EU, South Africa, and California. The requirements for slope stability analyses are evaluated on a site-specific basis in Japan.

4.2.4 Base Liner System

Comparison of current regulations regarding permitted liner types is presented in Tables 16a through 16c. The permitted liner types in the different countries include composite, compacted clay, and natural geologic liners. South Africa allows consideration of site climate and landfill size in evaluating the appropriate base liner system to be applied. The liner types vary from none in communal sites (with daily intake of less than 25 tonnes per day) to double clay liner at medium or large wet sites (with daily intake above 150 tonnes per day and positive water balance, as defined in Section 4.1.5). In California, it is possible for very small rural landfills (receive less than 20 tons of

MSW per day) to be exempted from base liner requirements under specific conditions, such that the site would effectively have a natural geologic liner system. All five countries allow some type of single clay liner or natural barrier in lieu of a composite liner system. The minimum allowable thickness of the single clay liner or natural barrier varies from approximately 1 foot to 17 feet. Under current California regulations, the owner may propose an engineered alternative to the prescriptive liner system, but alternative base liners must be composite (in other words, they must include a geomembrane component over a constructed or manufactured clay layer).

4.2.5 LCRS

Discussions of current regulations regarding permitted leachate systems are presented in Table 17. There are limited requirements in most current regulations in the five countries regarding leachate systems. In South Africa, leachate systems are not required in any communal site or in any dry site. However, at larger sites in wet areas, a minimum 0.15 meter thick drainage layer is required; containment requirements under a leachate drain at an MSW landfill in South Africa are the same as for a hazardous waste landfill. Australia (Victoria) and the EU also have requirements of a minimum 0.3 meter and 0.5 meter thick drainage layer, respectively. California requires an LCRS for all Class III MSW landfills that have a liner. The thickness of the LCRS is not specified in California. In addition, Australia (Victoria) also has a requirement for maximum head build-up over the liner. California incorporates the federal maximum of less than 30 centimeters of head build-up on the base liner and also requires no build-up of hydraulic head on the liner (except in the sump where the minimum allowable head for efficient pump operation is allowed).

4.2.6 Landfill Closure (Final Cover System)

Landfill closure incorporates various activities including but not limited to design and construction of the gas collection system, final cover system, and surface water drainage system. Gas collection and other components of landfill gas control are discussed in Section 4.2.8 and are presented in Table 20. Surface water drainage is discussed with the general design requirements in Section 4.2.3 and is presented in Table 15. Discussions of regulations related to cover systems are discussed in this section and presented in Tables 18a through 18c.

Requirements for final cover systems were found in the regulations from Victoria (Australia), the EU, Japan, and South Africa. While the EU has a general requirement that final covers have a minimum 0.5 meter drainage layer, specific requirements for final cover systems are included in individual EU countries' regulations, which were not reviewed for this study. Brazil has a requirement for vegetative cover, but none for an infiltration control layer. None of the countries surveyed requires a composite final cover. The most detailed final cover system requirements are provided by Australia (Victoria) and South Africa. South Africa allows consideration of site climate and landfill size in evaluating the appropriate final cover system to be applied. California does not require a composite final cover system, but specifies a performance standard that the final cover's throughflow must be equal to or lower than that of the base liner system. California does allow for the use of approved engineered-alternative cover systems, provided they comply with the intent of the regulations, so that site-specific conditions may be considered without prescribing different types of covers for different types of sites.

4.2.7 Post-Closure Maintenance Requirements

Discussions of regulations related to post-closure requirements are presented in Table 19. Very limited information was found regarding post-closure maintenance requirements. However, one notable regulation is that Australia (Victoria) and Japan define the end of the post-closure monitoring period based on the results of site-specific groundwater monitoring. By comparison, California

requires a minimum 30-year post-closure maintenance period (to be extended as long as wastes pose a threat to groundwater quality, public health and safety and the environment).

4.2.8 Landfill Gas Control Regulations

Landfill gas control regulations of different countries are compared in Table 20. No information was identified regarding air regulations in Japan or Brazil. Australia (Victoria), the EU and South Africa all have applicability triggers for landfill gas control requirements based on the size of the landfill or type of population served. Australia (Victoria) requires that landfill covers include a mulch layer to oxidize fugitive emissions. The most specific gas monitoring and reporting requirements of the countries reviewed are found in South Africa.

5 Discussion of Selected Regulations and Their Applicability to California

5.1 Introduction

The scope of this project includes examining the media impacts of groundwater, surface water, and air and the incremental cost and potential environmental protection benefit of the eight selected states' and five selected countries' regulations. In accordance with the scope of work, this task will identify elements of those selected states' and countries' regulations, which, if applied to California, could possibly improve or enhance California's multimedia regulations pertaining to MSW landfills.

A direct quantitative evaluation of the impacts of any particular state's or country's regulations on the environment is beyond the scope of this study. Therefore, the evaluation of the potential for the selected regulations to protect the environment, result in incremental costs, and be applied to conditions in California is based primarily on the author's assessment from experience in the landfill industry, input from California regulators, a review of available technical literature, and a review of the cross-media inventory (Task 2 of the Landfill Facility Compliance Study).

5.1.1 Basis for Selection of Regulations for Further Discussion

Not all of the state and country regulations discussed in Sections 3 and 4 represent a significant deviation from the federal Subtitle D or California regulations. For example, there is no detailed discussion in this report on air emissions testing requirements, since there were no significant differences identified between California emissions testing requirements and other states; and for other countries, California's air emission requirements were found to be more comprehensive. Further discussion of regulations that do not represent a significant deviation from California regulations is not warranted.

However, some of the state and country regulations selected should be examined further because they do represent a significant deviation in intent (such as a requirement for a reduction in waste volume prior to disposal through pre-processing, as opposed to no reduction in waste volume as is currently allowed in California) or detail (such as requiring a 100-foot separation from groundwater, as opposed to a 5-foot separation as is required in California) from regulations enforced in California.

In addition, some regulations were selected based on their pertinence to current topics being discussed in California. The state and country regulatory topics selected for further discussion are listed in Table 21. Sections 5.2 and 5.3 provide an evaluation of each of the selected regulations to define the intent of the regulation and its potential impacts if applied in California.

5.1.2 Criteria for Discussion of Regulations

To fully evaluate the potential impact of a selected regulation if applied to California, a list of subjects was developed for evaluating each selected regulation. The potential impact of each of these subjects on the selected regulations is discussed in detail in Sections 5.2 and 5.3. The subjects are described below.

Environmental Protection Benefit

This subject provides a qualitative assessment of expected environmental protection benefits of implementing changes to the regulations associated with each selected regulation.

The selected regulations are expected to benefit environmental protection, through the implementation of either more restrictive (statewide) or more flexible (site-tailored) regulations. The types of environmental benefits expected will be discussed for each selected regulation.

Cost Impact

This subject provides a qualitative assessment of expected cost impacts of implementing changes to California's existing landfill regulations associated with each selected regulation, discussing the anticipated relative impact to regulatory agencies, site owners and the general public.

Design Considerations

This subject provides a qualitative assessment of technological and analytical considerations and constraints that may affect the implementation of the selected regulations, as applicable, in California. For example, implementation of some regulations may require the use of technologies that are not yet proven or that pose excessive risk if not implemented properly. Similarly, implementation of some regulations may require a change in how landfills are designed.

Operational Considerations

This subject provides a qualitative assessment of operational considerations and constraints that may affect the applicability of the selected regulations to sites in California. For example, some selected regulations may be difficult to implement at certain sites because of site-specific operational constraints, which may also be closely related to cost impacts.

Comparison to Cross-Media Inventory

A review of the cross-media inventory of California landfills that was compiled during Task 2 of the Landfill Facility Compliance Study was performed, where appropriate, to identify compatibility of selected regulations with conditions in California. The cross-media inventory is used to identify sites in California to which the selected regulations may apply, and the performance of those sites under existing California regulations. While the cross-media inventory was not originally intended to be used as a basis for discussion in Task 6, some information has been found to be relevant in these discussions.

As described in Section 3.1.1, this report considers SWRCB requirements only for Class III facilities with respect to certain construction standards for seismic design and storm design. However, it should be noted that the MSW landfills included in the Task 2 cross-media inventory include both Class II and Class III units. The original goal of this inventory did not require differentiation between these two classes. Therefore, all site queries of the inventory completed as part of this task, other than for seismic design and storm design construction standards, include both Class II and Class III units.

As part of the Landfill Facility Compliance Study's Phase I report (Task 3) [GeoSyntec, 2003], data from the Task 2 cross-media inventory was used to analyze the relationships between various site characteristics and four environmental performance variables. The variables were defined as "In Corrective Action," "Has Gas Inspection Report," "Has Gas Enforcement Action," and "Has Surface Water Action." The Phase I report, which presents the results of Task 3, contains a complete definition of these variables [GeoSyntec, 2003]. The environmental performance of the sites included in the database with respect to these variables is presented in Task 6.

Documented Performance of Regulation (Internet Literature Search)

This subject provides the results of a limited Internet search to identify documentation of the effects of applying each regulatory topic. Because the selected regulatory topics represent deviation from the federal Subtitle D regulations, it is expected that the effects of implementation

may have been evaluated and documented by others. A search was performed for each of the selected regulatory topics to identify documentation of how the associated regulation has performed in only the respective state(s) or country(ies) referenced in this report. Queries were performed to obtain information on the performance of regulations only in the states and countries listed in Sections 3 and 4. To ensure equal consideration of each of the selected regulations, specific search criteria were defined based on keywords used in the discussion of each topic and the following sources were searched for documentation on the effects of each selected regulation, as applicable:

- Google (Internet search engine—www.google.com).
- American Society of Civil Engineers (ASCE) Civil Engineering Database (www.pubs.asce.org/cedbsrch.html).
- U.S. EPA Web site (www.epa.gov/ncepihom).
- Searchlight (general University of California database—searchlight.cdlib.org/cgi-bin/searchlight?science).
- Online Journal Search Engine (www.ojose.com).
- Electronic Journal of Geotechnical Engineering (www.ejge.com).
- Melvyl (University of California, Berkeley Library Catalog) (www.lib.berkeley.edu/enri).
- Physics and science search engines (www.phibot.org, www.scinet.cc, www.wasteinfo.com, www.eevl.ac.uk/eese/, www.er-online.co.uk].
- MSW Management magazine (www.forester.net/msw.html).
- Waste Age magazine (www.wasteage.com).

In addition, the Proceedings of the International Waste Management and Landfill Symposium, Sardinia, Italy (1999, 2001 and 2003) were reviewed for pertinent literature.

5.2 Selected Regulations From Other States

The regulations discussed in this section were selected from the State landfill regulations summarized in Section 3 based on the perceived significance of their deviation from federal Subtitle D and California regulations.

5.2.1 Siting Regulations

Separation Between Waste and Highest Groundwater (Table 3a)

Each of the eight states offers a slight variation to the California requirement for a 5-foot separation between waste and underlying groundwater groundwater (there is no federal requirement). Other than New Mexico, all of the eight states, including California, have requirements ranging between 0 and 10 feet. New Mexico's requirement differs the most significantly from California's by requiring a 100-foot separation between the bottom of the liner and groundwater. Engineered alternatives are not allowed.

The expected environmental protection benefit of imposing a 100-foot separation between the bottom of the liner system and groundwater is that, in the event the base containment system is compromised, the risk of groundwater contamination may be reduced. However, shallow groundwater (less than 100 feet below ground surface) occurs in many parts of California, precluding the development of new

landfills in these areas if this regulation were to be implemented. Groundwater is expected to be deeper than 100 feet below ground surface only in arid portions of California. Therefore implementing a requirement for siting landfills only at sites with groundwater greater than 100 feet below ground surface may be impractical, especially in the northern half of the state, where groundwater is generally shallow.

A review of the Task 2 cross-media inventory of California landfills reveals that 47 of 158 existing active landfills (approximately 30 percent) have a minimum depth to underlying groundwater greater than 100 feet below waste. These landfills are located primarily in rural or suburban areas of low population density, far from the source of waste, and mostly in the southern half of the state. The results of the Task 3 analyses indicated that there was no statistically significant relationship between the depth to underlying groundwater and the groundwater-related environmental response variable. However, of the 47 landfills, 11(23 percent) were in the category "In Corrective Action."

The potential cost impact of implementing this regulation is expected to be associated with increased transportation costs to haul waste from the source to a remote disposal site. It is expected that these costs would primarily be incurred by the waste haulers and passed on to the public. There are also potential environmental risks associated with hauling waste long distances, such as resource depletion from the use of fuel and air pollution from exhaust.

By limiting the construction of new landfills to arid regions with deep groundwater, it is expected that landfills would be fewer and larger. It is expected that some economic benefits due to economies of scale on the landfill site could be experienced.

There are no expected design impacts associated with the implementation of a landfill siting requirement for a 100-foot separation from groundwater.

An Internet literature search of the sources listed in Section 5.1.2 did not identify any documentation of the impact of depth to groundwater on environmental performance in New Mexico.

Engineered Alternatives to Separation From Groundwater (Table 3a)

Six of the eight states evaluated (all but New Mexico and Pennsylvania), as well as California, allow for engineered alternatives to the minimum allowable groundwater separation requirement. The alternatives listed include a more stringent liner system (Delaware), cut-off walls (New Jersey), temporary (New York) or permanent (West Virginia) drainage systems, other hydraulic controls (Washington), and "zone-of-saturation" landfills (Wisconsin). (Wisconsin's "zone-of-saturation" landfills allow construction of a landfill base liner below the water table if subsurface soils are "fine-grained" and require an underdrain if anticipated forces on the underside of the liner warrant.)

A review of the cross-media inventory indicates that the following engineered alternatives to the groundwater separation requirement have been allowed in California:

- Blanket underdrain (gravel and geocomposite).
- Dendritic pipe/gravel trench subdrain.
- Perimeter slurry wall with groundwater extraction.

Variations of these engineered alternatives have been implemented at 15 of the 27 existing active landfill sites in California that have groundwater within five feet of the waste. Most of the remaining sites were constructed prior to the implementation of 23 CCR, Chapter 15 siting requirements and are thus exempt. Of the 27 sites with groundwater within five feet of the waste, 8 (30 percent) are in the category "In Corrective Action."

The similarity of the engineered alternatives that have been approved for implementation in California to those specified for use in other states demonstrates that a change to existing California regulations in this regard is unnecessary.

Distance From Wetlands (Table 3c)

New Mexico, Pennsylvania, and West Virginia all have more stringent landfill siting criteria than California with respect to the proximity of the landfill to wetlands. California includes the federal requirement by reference, which allows siting of a landfill within a wetlands if no adverse impact can be demonstrated. New Mexico, Pennsylvania, and West Virginia do not allow siting of a landfill within a distance of a wetlands (specific distances vary by state). New Mexico is the most restrictive with a 500-foot minimum distance requirement.

The anticipated environmental protection benefit of implementing a landfill siting restriction based on proximity to wetlands is additional protection of California's existing wetlands.

Imposing this restriction on landfill siting may result in increased cost to procure a landfill site that is not within a wetlands area. Additional cost may also be incurred to replace wetlands if the landfill site does not comply with the minimum allowable distance requirement. It is expected that this cost would be incurred by the landfill owner and passed on to the public. However, it is GeoSyntec's understanding that existing wetlands regulations enforced in California (which were not reviewed as part of this study) may require special operations and monitoring for sites near wetlands. Therefore, an economic benefit in the form of fewer restrictions may be realized by the landfill owner if the landfill is not in a wetlands area.

Landfill operations at a site located within a wetlands area may require operational practices that are protective of the sensitive habitat. By implementing a landfill siting restriction limiting the proximity to a wetlands, normal waste handling operations may be applied.

There are no expected design impacts associated with the implementation of a landfill siting restriction based on proximity to a wetland.

A review of the cross-media inventory indicates that at least 10 of 158 existing active MSW landfills (approximately 6 percent) in California are in the vicinity of a wetlands area. Of the 10 sites located near wetlands, 3 (30 percent) are in the status "In Corrective Action," 3 (30 percent) in the category "Have Gas Enforcement Action," 7 (70 percent) in the status "Have Gas Inspection Report," and 3 (30 percent) in the category "Have Surface Water Action." The introduction of a landfill siting restriction based on proximity to a wetlands area could preclude the construction of any future disposal units at these sites.

An Internet literature search of the sources listed in Section 5.1.2 did not identify any documentation of the impact of landfill proximity to wetlands area on wetlands performance in New Mexico, Pennsylvania, and West Virginia.

Distance From Water Supply Wells (Table 3c)

Six states have restrictions on location of a landfill with respect to water supply wells (or water sources). The minimum allowable distance varies from 300 feet if the landfill is downgradient of a water source to one-quarter mile if the landfill is upgradient of a water source (both in Pennsylvania). These six states' regulations are more restrictive than California (and federal) regulations, where there is no specific restriction for distance from a water supply well (or water source). However, it is not necessary to demonstrate "no impact to groundwater" in these six states. In California, part of the information that must be submitted by an owner to the regulatory agency when proposing a landfill includes the following (for the area within one mile of the facility): groundwater flow direction and

well location and design. The regional water quality control board (RWQCB) considers this information when considering whether to allow a landfill to be built and operated.

The perceived environmental protection benefit of implementing a landfill siting restriction based on proximity to a water supply source is additional protection of human health through protection of drinking water. However, the restriction imposed by these states considers only horizontal distance from a well in its siting criteria. There are many more factors than horizontal distance to a well that affect the potential environmental impact of a landfill on a groundwater well, including permeability of the strata, the direction and rate of flow, and the depth to the aquifer.

Imposing this restriction on landfill siting may result in increased cost to procure a landfill site that is not in proximity of a water source or, alternatively, the cost to relocate the water supply wells. It is expected that this cost would be incurred by the landfill owner and subsequently passed on to the public. However, it is expected that an economic benefit may be realized by the landfill owner in the form of less stringent groundwater monitoring requirements than if the landfill were in proximity of a water supply source.

There are no expected operational or design impacts associated with the implementation of a landfill siting restriction based on proximity to a water supply source.

A review of the cross-media inventory indicates that at least eight of 158 existing active MSW landfills in California have been sited in the vicinity of one or more water supply wells. Of the eight sites, five (63 percent) are in the category "In Corrective Action." The introduction of a landfill siting restriction based on proximity to a water supply source similar to Pennsylvania's could preclude the construction of any future disposal units at these sites.

An Internet literature search of the sources listed in Section 5.1.2 identified several documents that discussed the impact of existing landfills on adjacent water supply wells in Wisconsin, New Jersey, and Delaware. However, these papers did not include a discussion of the impact of the regulatory requirements for distance to water supply wells, so they have not been cited.

5.2.2 General Design Regulations

Evaluation of General Design Requirements and Submittals (Table 4a)

California requires submission of several of the design elements listed in Table 4a, especially in conjunction with the ROWD requirement (27 CCR, section 21710 et seq.). However, the following elements are required by one or more of the other states reviewed, but not specifically by California regulations:

- Geotechnical report.
- Liner stress analyses.
- Anchor trench analyses.
- Groundwater transport model.

The perceived intent of requiring additional submittals is to provide consistency and reliability in the designs so that the environmental impacts of landfill cells may be minimized. However, the associated economic burden placed on owners to develop the documents and the regulators to review them may not be warranted for all sites. Currently, California allows for additional submittals to be requested by the permitting agency when it is warranted by site-specific conditions.

It is expected that the only design impacts would be associated with the increased number of documents to be produced. The current standard-of-practice in California includes submittal of the report, analyses, and model listed above, if warranted by site-specific conditions.

Requiring additional design submittals may induce a change in design procedures, but it is not expected to changes operational procedures at the site.

No pertinent input to the cross-media inventory was identified regarding the above design submittals; therefore, no query of the database was performed.

An Internet literature search of the sources listed in Section 5.1.2 did not identify any documentation of the impact of requiring additional design submittals.

As an alternative to changing the state regulations to require additional submittals for all sites, several states have produced non-enforceable general guidance documents to define standards for the design and construction of solid waste disposal facilities. These documents provide recommendations, but are not enforceable and allow for adjustment based on site-specific conditions. The performance of landfills in states with general guidance documents has not been evaluated as part of this study. However, the development of general guidance documents for landfill design and construction in California may be an appropriate alternative to imposing regulations requiring additional submittals. Based on discussions with current California regulators, it seems that the development of guidance documents has been considered previously in California, but was not pursued due to a tendency for them to be viewed as "underground regulations."

Requirements for Liner Performance Evaluation (Table 4b)

New Jersey regulations require a site-specific performance evaluation of all natural geologic, single clay, and single composite liner systems using a three-dimensional mass transport model. Similarly, Washington requires a performance evaluation for alternatives to the prescriptive single composite liner system. The purpose of a liner performance evaluation is to estimate the amount of leakage through the liner system expected under site-specific climate, cell configuration, waste characteristics, liner characteristics, and subgrade characteristics. Existing California regulations do not require a performance evaluation for the prescriptive single composite liner (or engineered alternatives), but allow permitting agencies to require one. In recent years, the Central Valley and North Coast Regional Water Quality Control Boards have required that landfill owners submit liner performance evaluations for new waste management units, even if they comply with prescriptive standards, to demonstrate that any proposed liner system is sufficiently protective.

The potential environmental protection benefit of requiring a performance evaluation for the prescriptive single composite liner system is that it provides a means for predicting the potential for a proposed landfill cell to adversely impact the environment prior to construction of the cell. However, the results of a transport model are subject to the reliability of the model and its input parameters, as well as the technical expertise of the designer. In addition, existing sites collect monitoring data, which should be considered in the execution of a model. For any site where reliable monitoring data is available, the model should be calibrated against it. A recent study of landfill operations data [U.S. EPA, 2002) has found that "Subtitle D single composite liner systems meeting federal minimum design criteria can achieve a very high hydraulic efficiency and are capable of preventing adverse impacts to groundwater," such that requiring a liner performance evaluation for the approval of a prescriptive single composite liner system may not be warranted.

The potential economic impact of requiring a performance evaluation for the prescriptive single composite liner system is associated with engineering cost to perform the evaluation and regulators costs to review and rule on it. In addition, if a model is developed without being calibrated against available monitoring data, the construction of a more protective (and probably more expensive) liner

system may be required. These costs would be incurred by the landfill owner, and subsequently passed on to the public.

No operational constraints associated with requiring a liner performance evaluation have been identified.

The technical constraints associated with requiring a liner performance evaluation are associated with the development of the transport model and the interpretation of results. Many input parameters are required by such models, and many assumptions must be made that affect the output of the model. To evaluate the leakage rate out of the landfill, weather data, soil data, and landfill design data are required. To predict concentrations at the point-of-compliance, subsurface material data, subsurface flow data, and chemical concentrations must be known (or assumed). As stated earlier, the reliability of the model is dependent on the reliability of the input parameters. Interpretation of the results should consider the reliability of each of the input parameters.

No pertinent input to the cross-media inventory was identified regarding liner performance evaluation; therefore, no query of the database was performed.

An Internet literature search of the sources listed in Section 5.1.2 did not identify any documentation (other than that cited above) of the impact of requiring a landfill performance evaluation on groundwater quality.

Surface Water Design Storm Requirements (Table 4b)

California requires that surface water systems at Class III MSW landfills be designed to control a 100-year, 24-hour storm. This requirement is considerably more strict than those in the other eight states, which are consistent with the federal requirement of design for a 25-year, 24-hour storm. The California requirement was first included in the Title 23, Chapter 15 rulemaking. California is known for high-intensity, short-duration storms. Since 1950, all 58 California counties have been declared flood disaster areas no fewer than three times [California Department of Water Resources, 2003].

The potential environmental impacts of designing for a less severe storm are based on the capacity of the surface water system. If the capacity of the surface water system is not sufficient to control a larger storm, the impacts of overflow may include:

- Erosion of the cover system and possible waste or sediment discharge to surface water.
- Increased leachate generation due to infiltration of surface water into waste.
- Uncontrolled discharges of surface water off-site.

The potential economic impacts of designing for a less severe storm include reduced cost of initial construction of the surface water control system, but higher costs associated with maintaining the system and monitoring surface water discharges. These costs also extend into the post-closure care period.

No significant design constraints associated with a less severe storm have been identified. Operational constraints are associated with increased monitoring of the performance of the surface water system during storms and maintenance of the surface water system during and after storms.

No pertinent input to the cross-media inventory was identified regarding design storms; therefore, no query of the database was performed.

An Internet literature search of the sources listed in Section 5.1.2 did not identify any documentation of the impact of design storm selection in California.

5.2.3 Base Liner System Regulations

Allowance of Natural Geologic Liner or Single Clay Liner (Table 5b)

Natural geologic or single clay liners are not specifically allowed by either federal or California regulations, except for that part of the MSW landfill that had received waste prior to the landfill's applicability date under federal regulations (40 CFR, Part 258, section 1). The U.S. federal regulations currently allow a site to be exempted from landfill design (Subtitle D, Subpart D—40 CFR, Part 258, section 40) if certain criteria can be met. The site must:

- Receive less than 20 tons of MSW per day (on an average annual basis).
- Show evidence of no existing groundwater contamination from the MSW unit.
- Serve either a community that is unable to transport waste to a regional facility for at least three consecutive months annually or a community with no practical waste disposal alternative if the site receives less than 25 inches of precipitation annually.

California has adopted these exclusion criteria by reference to the federal regulations, so that it is possible for a very small landfill to be exempted from base liner requirements under specific conditions, such that the site would effectively have a natural geologic liner system.

Under current California regulations, the owner may propose an engineered alternative to the prescriptive liner system, but alternative base liners must be composite (that is, they must include a geomembrane component over a constructed or manufactured clay layer). For steep side slopes, the liner design can be an extra-thick geomembrane over a prepared natural geologic material base. For all such alternatives, the owner must successfully demonstrate that the environment is equally protected (compared to the use of the prescriptive liner) and that the prescriptive design is burdensome. A single clay liner is not allowed as a base liner for new areas to receive waste under current California regulations. It should be recognized, however, that prior to Subtitle D and the SWRCB's Resolution 93-62, SWRCB regulations allowed single clay liners or natural geologic liners for Class III landfills. This was changed, in part, to comply with the minimum standards of Subtitle D. The area at a landfill that was already covered by waste as of the landfill's general federal applicability date is exempt from the federal and California single composite liner standard, but all portions outside of that area must be composite-lined.

Delaware, New Jersey, and Wisconsin all allow use of a single clay liner or natural geologic liner under specific site conditions. Washington does not require installation of a liner in arid areas (in other words, natural geologic liners are allowed), if specific environmental protection criteria can be met. Conceptually, natural geologic liners or single clay liners provide a more flexible approach to liner design, where site-specific conditions allow for them. However, an extensive study of such landfills in California showed that it is very rare for site-specific climatic and geologic conditions to provide reasonable protection of underlying groundwater [SWRCB, 1995].

Federal Subtitle D regulations do not allow state regulations to be less protective of the environment than are federal regulations. Therefore, to be allowed by any state, natural geologic or single clay liners must be demonstrated to be as protective of the environment as federal regulatory requirements. However, if appropriate site and environmental protection criteria are not met, the potential environmental impacts of allowing a natural geologic or single clay liner may include soil and groundwater degradation.

If environmental protection criteria are met, regulations allowing the use of natural geologic or single clay liners in California may have a beneficial cost impact on landfill owners. In some cases, a single clay liner may be less expensive to install than the prescriptive Subtitle D liner.

There are no expected operational impacts associated with allowing natural geologic or single clay liners. One technical consideration is the reliability of hydraulic conductivity measurements of natural geologic liners. Natural formations are often heterogeneous, and hydraulic conductivity may not be consistent across the site. It may be beneficial to include a requirement for recompacting the subgrade if a natural geologic liner is employed, as is required in Delaware.

A review of the cross-media inventory was performed to identify the subgrade materials at California landfills. Thirty-four of 158 existing active MSW landfills in California have silt/clay subgrade materials, and may be candidates for natural geologic liners. Of the 34 sites, 15 (44 percent) are in the "In Corrective Action" status, whereas 33 percent of all 158 existing active MSW landfills are in the "In Corrective Action" status. In addition, as reported in the Landfill Facility Compliance Study's Phase I (Task 3) report [GeoSyntec, 2003], of 224 studied MSW landfills, 58 are located in desert areas and 9 are located in high desert areas (both based on an average annual rainfall of less than 10 inches), indicative of arid climate conditions. Therefore, adopting Washington's criteria, 67 studied sites in arid regions of California could be considered for natural geologic liners.

A review of the cross-media inventory was performed to identify the number of existing medium and large MSW landfills in California (defined as receiving greater than 165 tons of waste per day) with no liner or with a clay-only liner. Fifty-four of 224 existing medium to large MSW landfills in California have no liner or a clay-only liner. Of these 54 sites, 21 (39 percent) are in the "In Corrective Action" status as compared to 33 percent of all existing active MSW landfills that are in the "In Corrective Action" Status.

An Internet literature search of the sources listed in Section 5.1.2 was performed. One report was identified that was developed by the State of Illinois Environmental Protection Agency titled *A Study of the Merits and Effectiveness of Alternate Liner Systems at Illinois Landfills*, which includes a comparison of liner requirements of 35 states. The conclusions of this report include the following statement: "Based on Wisconsin's experience with clay liner design and evaluation of performance monitoring data from numerous facilities, it was concluded that properly designed and constructed clay liners along with an efficient leachate collection system can provide a high level of groundwater protection at solid waste disposal facilities as reported in the 1997 Wisconsin study. The performance of the municipal solid waste landfill depends more on the functioning of the leachate collection and removal system than on the number of liners used, according to Lee and Jones-Lee (1994)" [Munie, 2003].

In addition, an article was reviewed which indicates that Washington's rules for arid climate landfills were under review prior to the 1993 rule update [Landfill Price Digest, 1991]. This article states that "Communities in the eastern part of the state have benefited considerably from the less stringent requirements for arid areas." This article also indicates that in conjunction with this review a report on the minimum functional standards for solid waste management facilities was being prepared, though this document was not located. It has not been identified which, if any, of the Washington state landfill requirements were changed in the 1993 update.

Design and Construction of Liner Components (Clay and Geosynthetics) (Table 5c)

Several states have specific requirements regarding the design and construction of components of the single composite liner system. The regulations imposed by the various states include both prescriptive and performance-based requirements. New Jersey requires that anchor trenches have a minimum 24 inches of run-out at the top of slope, that anchor trenches be 12 to 16 inches deep, and that minimum construction testing requirements be met. New Mexico requires design for tensile forces in the geomembrane where slopes have a ratio steeper than 4 to 1 (horizontal to vertical) considering interface friction between liner components. West Virginia requires that several anchor trench and liner tension design parameters be met, specifies geomembrane seam orientation on slopes, and does

not allow particles greater than 2 inches in the clay component. Wisconsin specifies maximum and minimum slope requirements for sidewalls, requires design of anchor trenches, specifies geomembrane seam orientation on slopes, specifies vehicle loading requirements, specifies time limitations for covering geomembrane after placement, and requires specific clay characteristics. There are no such geosynthetic design or construction requirements defined in California regulations.

The intent of imposing design and construction standards in the regulations is to provide consistency and reliability so that the environmental impacts of landfill cells may be minimized. Design and construction standards add an additional means of protection against improper design by inexperienced designers and regulators. However, specifying prescriptive design requirements (such as specified run-out length, anchor trench configuration, or slope angle limitations) without associated performance-based requirements (such as design for tensile forces) may have a negative environmental impact by hampering the performance of the liner system.

Specifying design and construction requirements may have the side effect of being unnecessarily restrictive and limiting disposal potential of some sites. For example, by altering the anchor trench design or angle of the side slopes, the configuration of a cell may be optimized while protecting the liner from excess tension. Placing prescriptive limitations on these parameters without considering the performance of the liner may limit the capacity of the landfill. The economic effects associated with inefficiencies in cell design if the liner system is not designed on a site-specific basis may include reduced cell volume and the cost of premature expansion into other areas or premature closure. In addition, applying prescriptive limitations to the characteristics of the clay layer without consideration for performance may require clay to be imported from offsite sources. Importing clay material may be prohibitively expensive for some sites. These costs could be significant and would be incurred by the landfill owner and subsequently passed on to the public.

It is expected that implementation of any construction-related regulations and some design-related regulations would have an impact on site design and operations. However, the potential impacts would have to be identified on a case-by-case basis for any constraint considered for implementation.

Regulations regarding design and construction of components of the single composite liner would have to be written in such a way as to be compatible with regulations allowing the use of engineered alternative liner systems.

No pertinent input to the cross-media inventory was identified regarding design and construction of liner components as it relates to these regulations; therefore, no query of the database was performed.

An Internet literature search of the sources listed in Section 5.1.2 did not identify any documentation of the impact of including design- and construction-related constraints in landfill regulations for the various states discussed above.

It should be recognized that several states and the federal government have produced non-enforceable general guidance documents to define standards for the design and construction of solid waste disposal facilities. These documents provide recommendations, but are not enforceable and allow for adjustments for site-specific conditions. The performance of landfills in states with general guidance documents has not been evaluated. However, the development of general guidance documents for landfill design and construction in California may be an appropriate alternative to implementing prescriptive and performance-based design and construction regulations. Based on discussions with current California regulators, it seems that the development of guidance documents has been considered previously in California, but was not pursued due to a tendency for them to be viewed as “underground regulations.”

Requirements for Double Liner Systems (Table 5d)

Delaware, New Jersey, and New York regulations stipulate conditions in which double liners must be used. Delaware requires a double liner system when the landfill cell is underlain by an aquifer that may be used for water supply. New Jersey requires a double composite liner system when bedrock is near the surface and groundwater is used as a water supply. New York requires a double composite liner system for all mixed solid waste landfills, but on side slopes (greater than 25 percent slope) only the geomembrane component of the primary liner (plus the leak detection layer and secondary composite liner) is required. California has no existing regulations requiring a double liner system, but allows permitting agencies to require one.

The potential environmental protection benefit of requiring a double liner system under specified conditions would be increased protection of the environment. It should, however, be recognized that a recent study of landfill operations data [U.S. EPA, 2002] has found that "Subtitle D single composite liner systems meeting federal minimum design criteria can achieve a very high hydraulic efficiency and are capable of preventing adverse impacts to groundwater." Therefore, cost-benefit analyses may suggest that, except in limited cases, the incremental cost of constructing a double liner system may outweigh the environmental benefit.

No significant changes to design or operations are expected in conjunction with double liner systems.

The addition of a requirement for double liner systems under specific conditions may necessitate the addition of other associated regulations, such as monitoring requirements for the leak detection and collection layer. Double liner system regulations appear to be otherwise compatible with existing California landfill regulations.

A review of the cross-media inventory was performed to identify double-lined cells at California landfills. At the time the database was developed, three of the 224 existing landfills in California, Rock Creek Solid Waste Facility, Azusa Reclamation Company Landfill, and CWMI Kettleman Hills Facility, were identified as having a double liner system in a portion of a cell (beyond the LCRS sump) or a full cell. However, the current list of non-hazardous waste landfills in California with double composite liner systems as identified by the SWRCB includes five additional sites: Sacramento County (Kiefer) Landfill, Western Regional Sanitary Landfill, Ostrom Road Landfill, Fink Road Landfill, and the City of Santa Maria Refuse Disposal Site. Several other landfills are currently constructing double composite liners. Between 1998 and 2001, six of these seven sites were in the "In Corrective Action" category. The requirement for double liners at the additional five sites not indicated in the cross-media inventory may have been in response to the corrective action, but this has not been verified.

An Internet literature search of the sources listed in Section 5.1.2 was performed. One report was identified that was developed by the State of Illinois Environmental Protection Agency titled *A Study of the Merits and Effectiveness of Alternate Liner Systems at Illinois Landfills* [Munie, 2003], which includes a comparison of liner requirements of 35 states. The discussion in this report suggests that double liners are costly to construct and may provide ambiguous monitoring data due to liquid in the LDS from sources other than leachate. No data collected from states that require double liner systems was presented.

5.2.4 LCRS Regulations

LCRS Design Specifications (Table 6a)

Of the eight states reviewed, all eight have LCRS design specifications that are equivalent to the federal Subtitle D requirement for less than 30 centimeters of head build-up on the base liner. Only California has a more restrictive regulation that incorporates the federal maximum of less than 30

centimeters by reference and also requires no build-up of hydraulic head on the liner (except in the sump where the minimum allowable head for efficient pump operation is allowed).

By strict interpretation, California's regulation suggests that the LCRS system must be constantly operating to remove leachate from the cell and does not allow leachate to become backed up into the cell even if the maximum head in the cell is maintained at less than 12 inches. If taken literally, California's requirement of no leachate head is not enforceable. The purpose of an LCRS is to collect leachate. If there is no head, there can be no flow, and thus no collection. It is GeoSyntec's experience that "no build-up of hydraulic head" has generally been interpreted in California to mean no build-up greater than 12 inches or greater than the thickness of the LCRS layer, whichever is less.

Given that California's requirement for no build-up of head on the liner is not defensible, its eventual removal (anticipated as part of the State's next regulatory revision) will neither increase nor decrease risk to the environment (specifically to groundwater); it will only improve clarity.

The operational impacts of removing California's head build-up restriction would also be minimal due to the state of the practice, which allows some head build-up in order to promote leachate collection and pump operation.

There are no significant changes to design methods expected in conjunction with the removal of the head build-up requirement.

No pertinent input to the Task 2 cross-media inventory was identified regarding leachate build-up; therefore, no query of the database was performed.

An Internet literature search of the sources listed in Section 5.1.2 did not identify any documentation (other than those cited previously in this section) of the impact of head build-up on groundwater quality in California.

Secondary LCRS/Leak Detection System Requirements (Table 6b)

West Virginia requires installation of a secondary LCRS (an LDS) below a single composite liner system. Existing California regulations do not require installation of (or design of) an LDS, but allow regulatory agencies to require one (typically in conjunction with a double liner system, but sometimes in conjunction with an alternative to the requirement for a five-foot separation of waste from groundwater).

The anticipated environmental protection benefit of requiring an LDS is that any leakage through the liner may be intercepted prior to dispersion into the subgrade. It should, however, be recognized that a recent study of landfill operations data [U.S. EPA, 2002] has found that "Subtitle D single composite liner systems meeting federal minimum design criteria can achieve a very high hydraulic efficiency and are capable of preventing adverse impacts to groundwater." Therefore, cost-benefit analyses may suggest that, except in limited cases, the incremental cost of constructing an LDS may outweigh the environmental benefit.

No significant changes to design or operations are expected in conjunction with an LDS.

Addition of a requirement for an LDS may necessitate the addition of other associated regulations, such as monitoring requirements for the leak detection layer. LDS regulations appear to be otherwise compatible with existing California landfill regulations.

A review of the cross-media inventory was performed to identify LDSs installed at California landfills. For the purpose of this review, LDSs were considered different from underdrains or subdrains installed as an alternative to the requirement for five feet of separation from groundwater. At the time the

inventory was developed, one of 224 existing landfills in California (Kettleman Hills Facility) was identified as having an LDS.

An Internet literature search of the sources listed in Section 5.1.2 identified one article that evaluates different methods of leak detection [National Network of Environmental Management Studies, date unknown], but no data collected from leak detection systems, in West Virginia or elsewhere, was presented.

Allowance of Leachate Recirculation (Table 6c)

Seven states and California allow the recirculation of leachate under certain restrictions. The New Mexico regulations do not specifically discuss the recirculation of leachate. The current California regulation regarding leachate recirculation specifies that the leachate may be returned to a composite-lined portion of that landfill, as long as the discharge does not exceed the moisture-holding capacity of the waste, and with approval from the RWQCB. Differences from the California requirements applied in other states are summarized, as follows.

- New Jersey requires that leachate recirculation not be used as a primary disposal method, but allows the process to be used as part of a leachate management system to enhance the degradation of waste.
- New York requires a double liner in any cell where leachate recirculation is practiced. Six months satisfactory performance of the primary liner system must be demonstrated prior to commencing leachate recirculation. The leakage rate of the primary liner cannot increase beyond 20 gallons per acre per day (when measured over a 30-day period) due to the introduction of leachate.
- Pennsylvania stipulates that the leachate must not be classified as a hazardous waste to be used for recirculation.
- Washington specifically allows for the recirculation of wastewater resulting from an emergency.
- West Virginia requires that an approved piping system installed under intermediate cover soil be used to recirculate the leachate.

These differences represent a step beyond the California regulation and stipulate additional requirements that may provide further protection of the environment while still allowing leachate recirculation. These additional requirements may be appropriate in their respective states where site conditions may be consistent statewide. Likewise, they may be appropriate in states with other more restrictive regulations (such as a requirement for double liner systems). The regulations may require additional constraints or blanket specifications for control of leachate recirculation activities. However, in California, where there are a large number of landfills distributed over highly diverse regional conditions, the decision to allow leachate recirculation has been the responsibility of the individual RWQCBs, so long as the receiving portion of the landfill is composite-lined. If they decide to allow leachate recirculation, the RWQCB may also apply additional constraints to address site-specific conditions.

The potential economic impact of adding blanket constraints over the implementation of leachate recirculation in the California regulations is that the efficiency associated with site-specific consideration by the RWQCB may be lost. Sites may be required to conform to additional requirements that are not warranted by site-specific conditions.

It is expected that implementation of some additional restrictions on leachate recirculation may have an impact on site design and operations. However, the potential impacts would have to be identified on a case-by-case basis for any constraint considered for implementation.

Addition of some constraints on leachate recirculation may necessitate changes to other associated regulations, such as monitoring or liner requirements. However, impacts on other existing regulations would have to be considered on a case-by-case basis for each constraint being considered.

A review of the cross-media inventory was performed to identify California landfills where leachate recirculation has been implemented. At the time the database was developed, 6 of the 224 studied MSW landfills in California were identified as performing leachate recirculation. Of the six sites, two (33 percent) are in the category "In Corrective Action," none are in the category "Have Gas Enforcement Action," three (50 percent) are in the category "Have Gas Inspection Report," and three (50 percent) are in the category "Have Surface Water Action."

An Internet literature search of the sources listed in Section 5.1.2 identified one article that presents the results of long-term monitoring of leachate and gas quality at two facilities in Delaware practicing leachate recirculation, although no leak detection monitoring was performed [Morris, 2003]. The study reported enhanced degradation of waste and small improvement to leachate quality. Another article was identified entitled "Landfill Bioreactors: A New York State Regulatory Perspective" [Phaneuf, 2000]. This article suggests that New York State's requirement for a double-liner system at all MSW landfills allows the option of leachate recirculation to be considered. At the time the article was written, there were 38 double-lined landfills in that state. Although the number of sites practicing leachate recirculation is not defined, the article indicates that "Based on environmental monitoring data and facility reporting…, the division [of the New York State Department of Conservation] has not seen, nor is aware of, any groundwater-related impacts attributable to these [38] double-lined landfill operations" [Phaneuf, 2000].

5.2.5 Final Cover System Regulations

Site-Specific Considerations for Final Cover Systems (Table 7a)

New York and Washington have site-specific components to their final cover system requirements. New York bases the final cover type on the configuration of the landfill (lined and operating after October 1993). For flat areas (slopes less than 25 percent) a composite cover system is required, but for steep areas only a geomembrane or a soil cover is required (not both). In Washington, a composite cover system is required in non-arid regions of the state, but in arid regions only the soil component is required.

California, on the other hand, does not require a composite cover, but specifies the following criteria for the final cover's protective barrier:

- Minimum 1-foot thick compacted soil layer with hydraulic conductivity equal to the hydraulic conductivity of the base liner; or
- Minimum 1-foot thick compacted soil layer with hydraulic conductivity less than or equal to 1 x 10^{-6} cm/sec (typically allowed if no base liner is installed); or
- Another design with a correspondingly low through-flow rate.

The corresponding federal performance standard for final cover systems (40 CFR, Part 258, section 60(a)(1)) is similar, but focuses only on "permeability." The USEPA has not opposed California's broader standard, which opens the door for the use of thick, loosely compacted soil-only "monocover" or "evapotranspirative" final cover systems. Therefore, the intent of California's regulation, to open up the scope of options to any approach that meets the throughflow-based performance standard, is

similar to those in Washington and New York, which allow for the consideration of site-specific conditions in the design of a final cover system. The similarity of the regulations defined in California to those applied in other states demonstrates that a change to existing California regulations in this regard is unnecessary.

5.2.6 Post-Closure Regulations

Post-Closure Land Use Restrictions (Table 8)

California and five of the states included in this study have post-closure land use restrictions that are comparable to the federal requirement. However, three states (Delaware, Pennsylvania, and Wisconsin) include varying degrees of additional requirements or restrictions beyond the federal restrictions. Pennsylvania requires submission of a post-closure land use plan to propose and evaluate alternative post-closure uses for the revegetated site. By comparison, in California one or more proposed land uses must be presented in the closure plan submitted to the regulatory agencies. Wisconsin restricts use of the closed site for agricultural purposes or for the construction of buildings, and restricts the excavation of waste. Delaware poses the most restrictions by not allowing any post-closure activities on the landfill site and limiting access to maintenance personnel.

The potential environmental protection benefit of imposing additional post-closure land use requirements or restrictions is dependent on the specific requirement or restriction. For example, requiring submission of a post-closure land use plan may facilitate the beneficial reuse of a landfill site, having an overall beneficial impact on the environment. Conversely, not allowing any post-closure activities inhibits beneficial reuse, but protects human health and the environment by restricting public access to the site and eliminating the potential for improper reuse of the landfill site.

Likewise, the potential economic impact of imposing additional post-closure land use requirements or restrictions is dependent on the specific requirement or restriction. Requiring a post-closure land use plan represents an additional cost to the owner, but may serve to identify profitable post-closure land use alternatives. Conversely, not allowing post-closure use of the site may reduce the post-closure value of the parcel.

It is expected that the only design impacts would be associated with the increased number of documents to be produced. Changes in post-closure operations may be required, but are dependent on the specific regulatory requirement.

Compatibility of additional post-closure land use requirements/restrictions with other existing California landfill regulations is dependent on the specifics of the regulation, and would have to be considered on a case-by-case basis.

No pertinent input to the cross-media inventory was identified for post-closure land use; therefore, no query of the database was performed. However, a general search of the cross-media inventory identified Coastal/Santa Clara Landfill (closed prior to Subtitle D) as having been redeveloped as a golf course following closure of the landfill. It should be recognized that the inventory generally includes sites that have been operational after 1993, and thus does not include many sites that have been closed long enough for substantial post-closure development. There are many other MSW landfills within California that closed prior to 1993 but were not part of the cross-media inventory that have had beneficial post-closure developments.

An Internet literature search of the sources listed in Section 5.1.2 did not identify any documentation of the impact of post-closure land use regulations.

5.2.7 Groundwater Monitoring Regulations

Concentration Limits for Groundwater (Table 9)

Six of the eight states define the allowable concentration limits for groundwater contaminants using criteria similar to what is in the federal regulations—that is, the MCL, background, or health-based limits, as appropriate. Only California, New Mexico, and Wisconsin deviate significantly from the federal regulations. California and Wisconsin criteria for defining concentration limits in groundwater are similar in that both states recognize that background or some level above background may be appropriate. New Mexico differs from the other states, in that it defines different allowable concentrations depending if the site is in detection monitoring or in assessment monitoring. During detection monitoring, the concentration limit is taken as 50 percent of the groundwater protection standard—in other words, 50 percent is the concentration limit that triggers assessment monitoring. During assessment monitoring, the concentration limit is taken as 75 percent of the groundwater protection standard—that is, 75 percent is the concentration limit that triggers corrective action.

The New Mexico regulation for concentration limit is potentially less protective of the environment than the current California regulation because of how New Mexico's groundwater protection standard is defined. In New Mexico, the groundwater protection standard is defined for each constituent based on either background, MCL for groundwater, or a health-based alternative concentration, as appropriate; this is similar to the federal definition of the water standard. California's regulations base the concentration limit on background levels, unless an alternative CLGB is approved for use during corrective action. In California, except for a CLGB granted for use during corrective action, the concentration limit is background data set against which new data from a downgradient well is compared, using an approved statistical or nonstatistical data analysis method. This approach may be more protective than defining the concentration limit as a single number (such as 50 percent or 75 percent of the MCL), as is allowed for some constituents in New Mexico, because the New Mexico approach allows a no-response option for known releases that exceed background levels, but do not yet exceed the single-number concentration limit.

If California's current requirement for background level as concentration limit remains unchanged, it would be inappropriate to adopt only the portion of New Mexico's regulation that refers to trigger concentrations for assessment monitoring and corrective action. For example, to allow the use of a concentration limit equivalent to 50 percent of the water standard in detection monitoring would, in most cases, violate the current approach of investigating any release that is strong enough to be discerned from background levels. Therefore, if New Mexico's concentration limit methodology were adopted, its water standard would also need to be adopted, and the California Water Code would also have to be amended to allow low-concentration release to remain uninvestigated.

Because existing regulations allow the RWQCB to set the concentration limit to a CLGB with a value between background and the lowest applicable health-based standard for use as a clean-up goal during corrective action, there appears to be no substantial economic benefit to following the New Mexico regulation for concentration limits.

Adopting concentration limit (and water standards) regulations similar to New Mexico's would not necessarily change the way in which the site is monitored or how operations at the site are conducted.

No pertinent input to the cross-media inventory was identified for groundwater concentration limits; therefore, no query of the database was performed.

An Internet literature search of the sources listed in Section 5.1.2 did not identify any documentation of the impact of New Mexico's method for defining concentration limits.

Groundwater Monitoring System Requirements (Table 9)

Six of the eight states and California have requirements similar to the federal regulations for evaluating the number of wells required in the groundwater monitoring system. These states (and federal regulations) require a sufficient number of wells to adequately monitor groundwater quality. Only Pennsylvania and West Virginia specify a minimum number of allowable wells. These two states require a minimum of one background (upgradient) well and three downgradient wells.

Practically speaking, requiring a sufficient number of wells to monitor groundwater implies that at least one background well is installed. However, there would be no environmental protection benefit to specifying that a minimum of one background well be installed. On the other hand, specifying a minimum of three downgradient wells may be at times more, and at other times less, protective than California's requirement for "a sufficient number of wells." Based on interpretation of the California regulation, a landfill has a sufficient number of downgradient wells if there is no release location in the landfill that could produce a narrow plume that would escape discovery. Requiring a minimum of three wells provides no such safeguard for intercepting plumes.

Because the number of downgradient monitoring wells that may be required at a given site under existing California regulations varies, there is no quantifiable economic benefit to adopting a minimum standard for number of wells. At some sites, three wells would be more than would be required under existing California regulations, and at others three wells would be inadequate.

No changes to the design of the groundwater monitoring system are anticipated in conjunction with requiring a minimum number of groundwater monitoring wells. This is because the hydrogeologic conditions of the site would still need to be evaluated to verify that three down-gradient monitoring wells is sufficient. No changes to site operations would be required to adopt a requirement for a minimum number of groundwater monitoring wells.

A review of the cross-media inventory identified 37 of 224 California MSW landfills that received waste after October 9, 1993, as having fewer than three down-gradient monitoring wells. Nine of these 37 sites do not monitor groundwater, generally because groundwater is excessively deep or is not present beneath the site. The remaining 28 sites have a median disposal area of 17 acres, which is significantly less that the statewide median of 55.5 acres. Of these 28 sites, only 1 (4 percent) is in the category "In Corrective Action."

An Internet literature search of the sources listed in Section 5.1.2 did not identify any documentation regarding how specifying a minimum number of groundwater monitoring wells might impact groundwater quality.

Criteria for Corrective Action (Table 9)

The eight states reviewed, California, and the federal regulations all define slightly different requirements for their corrective action programs. However, the greatest deviation from the federal and California regulations was identified in the Wisconsin regulations. The Wisconsin regulations define a list of possible corrective actions that may be required depending on the severity of the groundwater impact at the site. These regulations also indicate that more comprehensive or rigorous actions may be required for hazardous constituents that exceed the established limits than for indicator parameters that exceed the established limits. It appears that the regulatory agency is bound to the range of responses indicated in the list and may not require an action that is not on the list. However the range of responses provided is so generic in nature that most possible responses would fall within the range. In California, corrective actions are proposed by the owner/operator and the selected action is approved by the regulatory agency, but no non-enforceable general guidelines are provided in the regulations for the degree of action that may be required for a specific problem.

The potential environmental protection benefit of specifying a range of corrective actions that may be required by the regulatory agency under different circumstances depends on the specificity of the list. The more specific it is, the greater the potential for environmental impact, positive or negative. If the list is very generic, like Wisconsin's, there may be no substantial change in environmental protection. However, defining a range of actions to be used as a non-enforceable general guideline by the landfill owners and regulatory agencies (but to which they are not bound) may be beneficial to the environment by providing an equitable standard for considering corrective action measures at all California sites.

Additionally, the potential economic impact of specifying a range of corrective actions that may be required by the regulatory agency under different circumstances is also dependent on the specificity of the range and is therefore uncertain. If the list of corrective actions is very generic, the economic impact on either the landfill owner or the regulatory agency would depend on what the owner decided to implement and what the agency approved.

Incorporating a range of corrective action options into the regulations may have the effect of streamlining the corrective action design process. It is not anticipated that incorporating a range of corrective action options into the regulations would have any appreciable impact on site operations.

No pertinent input to the cross-media inventory was identified for evaluating the impact of regulations considering a range of corrective action criteria; therefore, no query of the database was performed.

An Internet literature search of the sources listed in Section 5.1.2 did not identify any documentation regarding the impact of Wisconsin's regulation of corrective actions.

5.2.8 Landfill Gas Control Regulations

Performance Requirements (Table 10)

Generally, the federal regulations, the eight states, and California specify maximum explosive gas concentrations at the site boundary between 5 percent and 100 percent of the lower explosive limit (LEL). However, Wisconsin regulations also state that "the department may require the concentration of explosive gases not exceed detectable levels for that gas at the landfill property boundary" [WAC NR 506.7(4)] The criteria to define when this requirement must be applied was not specified.

The potential environmental protection benefit of requiring no detection of explosive gases (such as methane) at the landfill boundary is increased protection of human health and the environment.

The potential economic impact of requiring no detection of explosive gases is associated with increased costs to the landfill owner to provide:

- Additional gas extraction facilities.
- Additional gas control features (such as cut-off walls).
- Additional buffer from surrounding populations by extension of the property boundary.

It is expected that the cost of implementing these protections may outweigh the perceived benefit of no detection of explosive gases. A more cost-effective alternative may be to require enhanced protection (above the current requirement) only in the vicinity of sensitive receptors.

Changes in design or operations are expected to be associated with these additional control features.

No pertinent input to the cross-media inventory was identified regarding explosive gas monitoring; therefore, no query of the database was performed.

An Internet literature search of the sources listed in Section 5.1.2 did not identify any documents regarding the impact of explosive gas restrictions in Wisconsin.

5.3 Selected Regulations From Other Countries

5.3.1 Regulations for Special Handling of Waste

Requirements for Pre-Processing of Waste (Table 13)

The EU Landfill Directive calls for a strict limitation of biodegradable organic components of domestic waste entering the landfill with specified reductions required over time. This directive requires pre-processing of domestic waste by either thermal pre-treatment or mechanical-biological pre-treatment prior to disposal to achieve specified reductions in waste volume. Current California regulations do not require pre-processing of waste prior to disposal, other than the shredding of whole tires. However, many communities recover recyclable materials through curbside collection and at materials recycling facilities (MRF).

The potential environmental protection benefit of processing waste prior to disposal is reduced negative impact on all media (air, surface water and groundwater). By reducing the volume of degradable waste landfilled, the generation of leachate and landfill gases is expected to decline. Less airspace is used, thus extending landfill resources.

Some mechanical pre-processing operations, such as separation, also allow for the collection of inert recyclable materials that may otherwise end up in the landfill. Other mechanical pre-processing operations, such as shredding, homogenize the residual waste mass so that degradation within the landfill will occur more quickly. Biological pre-treatment, such as composting or anaerobic digestion, accelerates the biodegradation of the organic waste mass. Biogases produced during biological pre-processing are generated over a shorter timeframe than in the landfill, and can be more efficiently controlled with a properly designed system. Thermal pre-treatment, such as incineration, results in a significant reduction in the volume of waste to be landfilled, but the by-products of the process may require treatment prior to release or disposal. Pyrolysis, an alternative to incineration, appears to produce by-products that are less hazardous, but the process is new and the long-term environmental impacts of the by-products have not been evaluated.

Significant economic impacts are anticipated in conjunction with a regulation requiring pre-processing of waste. Pre-processing facilities are expensive to build and operate. Handling costs significantly increase by adding extra stops in the trip from source to landfill. In addition, some of the processes produce by-products or a residual waste stream that must be treated prior to release or disposal, increasing the cost of operating the system.

However, there are also several economic benefits to pre-processing waste. Depending on the process, there is a potential for revenue from the sale of recyclable materials, process by-products (such as fly ash as a construction material), biogases (such as methane), and heat. Reducing the volume of waste to be landfilled results in a lower need for airspace and reduced land procurement and construction costs. In addition, reduced leachate and landfill gas generation in the landfill may reduce the potential for releases from the landfill and subsequent costs for control systems or remediation.

Depending on who owns the pre-processing facility, the economic benefits may not be fully realized. For example, many existing MRFs separate out recyclable materials for resale, but do not take the additional step of reducing the particle size of the residual waste. Many MRFs are not owned by landfill operators, and thus the added financial benefit of lower airspace consumption is not an incentive for shredding waste. Even if the pre-processing facility were owned by the landfill operator, motivation to reduce residual waste particle size may not be high, since tipping fees are generally by weight, and weight is not reduced during the shredding process.

It should be recognized that members of the waste industry may choose to ship waste out of state for disposal rather than incur the costs associated with waste pre-processing in California. The economic impact of this should also be considered.

One consideration in evaluating the applicability of pre-processing requirements in California regulations is the physical and social setting (for example, population density, land use, and topography) of California in comparison to the EU. The EU member states are generally densely populated with little room for landfill expansion, causing a tangible need for a reduction in waste volume. While the population in California continues to grow, there is still space for new landfills in California. As such, the expected environmental benefit should be weighed against the cost of implementing pre-processing regulations when the need may not be as urgent in California as in the EU.

The incorporation of pre-processing facilities at the landfill site would result in significant changes to landfill operations. Considerable attention would shift from cell construction and filling to separation and volume reduction.

Changes in MSW characteristics associated with the reduction of biodegradable materials in the waste mass may warrant changes in design parameters and/or procedures. In addition, significant attention would be required to identify appropriate pre-processing options, based on site-specific waste and site characteristics. Some technologies, such as pyrolysis, are still being developed for domestic waste reduction, and may require extra attention if considered for full-scale implementation.

The addition of a requirement for the reduction of the waste volume prior to landfilling appears to be compatible with other existing California landfill regulations. However, compatibility of individual technologies with existing regulations would need to be considered on a case-by-case basis. For instance, incineration may not be compatible with existing air quality regulations.

A review of the cross-media inventory identified five of the 224 MSW landfills in the study that have proposed or implemented some form of waste pre-processing. Of the five sites, one is in the "In Corrective Action" status, no sites are in the "Have Gas Enforcement Action" status, three sites are in the "Have Gas Inspection Report" status, and two sites are in the "Have Surface Water Action" status. Many MRFs and incineration facilities not associated with a specific landfill exist in California, and are not included in the inventory.

An Internet literature search of the sources listed in Section 5.1.2 was performed. Several articles pertaining to the EU regulations regarding the pre-processing of waste were identified. Three of these are expected to include discussion pertinent to this study, but were not available for review at the time the Task 6 Report was being drafted [Crowe et al., 2002; Buclet, 2002; and Abert, 1985]. An article titled "Organic Waste Management With Respect to the EU Landfill Directive" was presented at the Sardinia Symposium [Kranert et al., 2001]. This article evaluates the effects of waste treatment operations under different hypothetical scenarios. Because the EU Landfill Directive is being implemented currently, the performance of actual sites cannot yet be evaluated. The results of the study suggest that with separation of recoverables and treatment of residual waste through incineration or mechanical-biological pretreatment, the volume entering the landfill and the potential for emissions can be reduced significantly.

5.3.2 Siting Regulations

Site-Specific Considerations in Location Selection (Table 14)

The EU provides flexibility in site selection to take into account site-specific conditions of a location, rather than provide a blanket set of restrictions applying to all landfills. By comparison, the California

regulations include specific requirements for separation from groundwater and address proximity to floodplains, wetlands, and airports (which are also addressed by the federal regulations).

The EU regulations require that "The location of a landfill must take into consideration…:

(a) the distances from the boundary of the site to residential and recreation areas, waterways, water bodies and other agricultural or urban sites;

(b) the existence of groundwater, coastal water or nature protection zones in the area;

(c) the geological and hydrogeological conditions in the area;

(d) the risk of flooding, subsidence, landslides or avalanches on the site;

(e) the protection of the nature or cultural patrimony in the area.

The landfill can be authorized only if the characteristics of the site with respect to the abovementioned requirements, or the corrective measures to be taken, indicate that the landfill does not pose a serious environmental risk" [from Official Journal of the European Communities, Annex 1 of Council Directive 1999/31/EC].

Prescriptive requirements are not indicated in the EU requirements quoted above, leaving flexibility for working with site-specific conditions. However, the lack of prescriptive requirements suggests that protection of the environment must be demonstrated prior to approving any site. Because existing California regulations do include prescriptive requirements, sufficient protection of the environment must be demonstrated only if those prescriptive requirements are not met. In addition to being addressed in California's Title 27 landfill regulations, site-specific siting requirements are also addressed during the California Environmental Quality Act (CEQA) environmental impact reporting process, which takes place prior to the permitting of a site.

The potential environmental protection benefit of allowing site-specific evaluation of siting criteria is that the most appropriate measures for protecting the environment can be used. However, by eliminating prescriptive requirements, consistency across sites is lost, making regulatory review of compliance more difficult.

The potential cost of allowing site-specific evaluation of siting criteria is associated with evaluation of site-specific conditions for environmental protection. It is expected that this cost would be incurred by the owner. However, it is expected that an economic benefit may also be realized by the landfill owner in the form of reduced potential for future remediation because the appropriate measures have been applied to protect the environment.

Allowing site-specific evaluation of siting criteria may increase design requirements, especially with respect to consideration of future landfill sites and development potential. No apparent impacts to landfill operations have been identified.

No pertinent input to the cross-media inventory was identified regarding compliance with siting criteria, therefore no query of the database was performed. However, Section 5.2.1 provides the results of database queries pertinent to other aspects of existing siting criteria.

An Internet literature search of the sources listed in Section 5.1.2 was performed. While several articles discussing the implementation of the new EU Landfill Directive were found (such as Gronow, 1999), no discussion of the impact of allowing site-specific siting criteria was identified.

5.3.3 Base Liner System Regulations

Multiple Prescriptions for Base Liners Based on Site Conditions (Table 16a)

South African landfill regulations specify different levels of prescriptive requirements for base containment based on the climate at the landfill site and the size and type of community served. At one end of the spectrum, small communal landfills in dry climates (where evaporation exceeds rainfall) do not require any type of base containment system. At the other end, medium or large landfills in wet areas require construction of a double clay liner system. By South Africa's definition, communal landfills receive up to 27.5 tons per day (tpd) (25 tonnes/day), small landfills receive 27.5 to 165 tpd (25 to 150 tonnes/day), medium landfills receive 165 to 550 tpd (150 to 500 tonnes/day) and large landfills receive more than 550 tpd (500 tonnes/day). The maximum deposition rate takes into account disposal rate at the time of construction, growth of the population served and life of the landfill. For example, a landfill which will serve a community with a very small initial rate of deposition (15 tonnes/day) that is growing at an average rate of 5 percent per year for a period of 50 years will need to be designed as a medium landfill rather than a communal landfill.

The federal Subtitle D regulations (Subpart D) currently allow a site to be exempted from landfill design (40 CFR, Part 258, section 40) requirements if certain criteria can be met. The site must:

- Receive less than 20 tons of MSW per day (on an average annual basis).
- Show evidence of no existing groundwater contamination from the MSW unit.
- Serve either a community that is unable to transport waste to a regional facility for at least three consecutive months annually or a community with no practical waste disposal alternative if the site receives less than 25 inches of precipitation annually.

California has adopted these exclusion criteria by reference to the federal regulations, so that it is possible for a very small landfill to be exempted from base liner requirements under specific conditions. It should be recognized that it appears that South Africa considers landfill size only during initial siting, whereas the current federal composite liner exemption, as implemented in California, is based on continued compliance with the conditions. Theoretically, adoption of the federal exemption establishes a two-tier system in California with respect to base liner requirements.

Under current California regulations, the owner may propose an engineered alternative to the prescriptive single composite base liner system, but alternative liners must also be composite (in other words, they must include a geomembrane component over a constructed or manufactured clay layer), except for steep side slopes, where the liner design can be an extra-thick geomembrane over a prepared natural geologic material base. For all such alternatives, the owner must successfully demonstrate that the environment is equally protected, compared to use of the prescriptive liner, and that the prescriptive design is burdensome. A single clay liner is not allowed under current California regulations as a base liner for new areas receiving waste. Under the current regulations, a liner performance demonstration or a double liner system may be required at the discretion of the regulatory agency.

A tiered structure would group California landfills by characteristics, such as size, climate, geology, and surrounding population, and prescribe the most appropriate liner system for each group. Groups with more protective minimum base liner requirements, such as a single composite liner system or a double liner system could be allowed to install the prescribed liner without performing a demonstration. For groups with less protective minimum base liner requirements, such as single clay liner, natural geologic liner, or a geomembrane liner, it may be appropriate to require demonstration of performance in conjunction with approval of the base liner system. Rather than follow California's current two-tier approach, which requires a single composite liner system at all new landfills that do

not meet the federal small rural landfill exemption, multiple tiers would be defined to address variable conditions across the state. This system would attempt to streamline the regulatory approval process and provide a more equitable standard for applying minimum liner requirements.

The type of regulatory structure imposed in South Africa attempts to pair the level of environmental risk with the level of protection required. Very small communal landfills are expected to pose lower environmental risk; therefore, no base containment system is required. However, medium and large landfills in wet areas pose a significant risk, and a high level of protection (specifically, a double clay liner system) is required. Therefore, if a tiered structure appropriate for the conditions found in California is developed, it is expected that its implementation would have a positive environmental impact by prescribing more protective liners at sites where the potential for environmental impact is greatest.

It should be recognized, however, that allowing minimal base containment at a landfill site based on a projection of population served by the landfill precludes that site from ever receiving more waste than allowed by the projection. If population growth exceeds projected rates, a new landfill site would need to be constructed. Exceeding the disposal rates allowed for the selected base containment system counteracts the purpose of the graded structure and may increase the potential for impacting the environment.

South Africa's graded structure for base containment requirements has the potential to reduce the economic burden on small communities with low population growth that intend to construct a landfill solely for their own use. As the population of California continues to grow and spread out from the metropolitan areas, this classification will apply to fewer and fewer communities. If a landfill is to be constructed in a small community with the intent of accepting waste from surrounding communities, more stringent base containment requirements would necessarily apply and no economic relief would be recognized. Likewise, it is expected that no economic relief would be experienced by landfills in medium to large communities.

Allowing site-specific evaluation of base containment system requirements may increase design requirements. No significant impacts to landfill operations have been identified.

Any regulation allowing a graded application of a base containment system should be written to comply with existing siting criteria. The suitability of a site being considered for landfill construction should be evaluated based on regulatory siting requirements before giving consideration to the socio-economic status of a community and the corresponding base containment system. In addition, if liner systems which are less protective than the current single composite liner system are included in the tiered structure, it may be appropriate to add a regulation requiring a liner performance evaluation, as discussed in Section 5.2.2.

A review of the cross-media inventory results in the following breakdown of 158 existing active California MSW landfills included in the database, based on waste acceptance rate and site climate.

Type of Site*	Number of Sites			
	Community Site (receives less than 27.5 tpd)**	**Small Site (receives 27.5 to 165 tpd)**	**Medium Site (receives 165 to 550 tpd)**	**Large Site (receives more than 550 tpd)**
Dry	12	14	10	15
Wet	9	11	28	59

*Dry sites: Desert or high desert (high deserts sites have less then 10 inches precipitation per year).
Wet sites: All other climate designations.
**Tpd= tons per day.

Of the dry sites, no community or small sites are in the category "In Corrective Action," 3 (30 percent) of the medium sites are in the category "In Corrective Action," and 4 (27 percent) of the large sites are in the category "In Corrective Action." Of the wet sites, 3 (39 percent) of the community sites are in the category "In Corrective Action," no small sites are in the category "In Corrective Action," 11 (39 percent) of the medium sites are in the category "In Corrective Action," and 31 (53 percent) of the large sites are in the category "In Corrective Action." These percentages can be compared to existing active California landfill sites as a whole, of which approximately 33 percent are in the category "In Corrective Action."

This data indicates that roughly one-third of the landfill sites are located in "dry"(desert or high desert) areas, with relatively even distribution in acceptance rate. Of the wet landfills, 80 percent are medium and large landfills (based on the South African designation).

In addition, a review of the cross-media inventory was performed to identify how many currently active landfill sites in California may be considered for exemption from Subtitle D design and monitoring requirements based on acceptance rate and annual precipitation. Fifteen sites were identified that meet this criteria. Of the 15 sites, only one (7 percent) is in the category "In Corrective Action." Three sites (20 percent) are in the category "Have Gas Enforcement Action," and 9 sites (75 percent) are in the category "Has Gas Inspection Report." No sites are in the category "Has Surface Water Action." However, a review of the WDRs for these sites identified only one, Loyalton Landfill, that has been specifically exempted from the Subtitle D requirements for base liner containment.

Findings from the Task 3, Landfill Facility Compliance Study Phase I report [GeoSyntec, 2003] similarly suggest that small, rural, unlined landfills in dry climates are less likely to be in the status "In Corrective Action" than other landfills. Conversely, large sites were found to be in wet areas, with more varied level of base liner protection, and more likely to be in the category "In Corrective Action" than smaller landfills. By contrast, in the North Coast and Central Valley regions of the RWQCB, the recent trend toward requiring liner performance evaluations suggests that the prescriptive single composite liner system may not be considered sufficiently protective by the regulatory community in these areas.

An Internet literature search of the sources listed in Section 5.1.2 was performed. Several papers were identified which address the topic of graded landfill base containment requirements in South Africa, though they all have the same author [Fourie et al, 1997; Fourie and Blight, 1998; and Rohrs, Fourie and Blight, 1999]. Two of these papers discuss the results of a study of six unlined landfills in South Africa with respect to environmental performance in light of the graded base containment regulation. The landfills were in both dry and wet areas of the country. The study found that some limited contamination had occurred in the immediate vicinity of the sites, but attributed most of the problem to operational issues. "The results of this study are shown to vindicate the graded approach to landfilling that is presently being implemented in South Africa [Fourie and Blight, 1998]."

5.3.4 Final Cover System Regulations

Multiple Prescriptions for Final Covers Based on Site Conditions (Table 18b)

South Africa has a similar tiered structure for prescribing final cover system components as it does for base containment system components. All communal landfills and small landfills at dry sites require no infiltration control layer. Small landfills at wet sites, medium landfills at dry sites, and large landfills at dry sites require a 1-foot-thick infiltration control layer with a maximum infiltration of 18 inches per year. Medium and large landfills at wet sites require an approximately 18-inch-thick infiltration control layer with a maximum infiltration of 18 inches per year.

California specifies the following criteria for the final cover's protective barrier:

- Minimum 1-foot-thick compacted soil layer with hydraulic conductivity equal to the hydraulic conductivity of the base liner; or
- Minimum 1-foot-thick compacted soil layer with hydraulic conductivity less than or equal to 1 x 10^{-6} cm/sec (typically allowed if no base liner is installed); or
- Another design with a correspondingly low through-flow rate.

The corresponding federal performance standard for final cover systems (40 CFR, Part 258, section 60(a)(1)) is similar, but focuses only on "permeability;" the U.S. EPA has not opposed California's broader standard, which opens the door for the use of thick loosely-compacted soil only "monocover" or "evapotranspirative" final cover systems. All sites in California must comply with closure requirements with no exemptions allowed. The federal closure standards of Subtitle D, Subpart F (40 CFR, section 258.60) are the only requirements that apply to all new landfills that received any waste after October 9, 1991, including those that closed soon enough to escape all the rest of the federal standards.

The potential environmental impacts of a tiered structure of prescriptive final cover system requirements are similar to the impacts of developing a similar structure for base liner systems, discussed in Section 5.3.3. It is the goal of this type of structure to apply an appropriate level of protection based on the potential for the landfill to impact the environment. However, as explained above, California's existing final cover design requirements allow any design that is likely to minimize through-flow to the underlying waste so that a cover may be designed to appropriately address site climate. Therefore, a tiered structure would be expected to provide no improvement to environmental protection at "dry" sites.

However, the current California regulations give no consideration to site size in the definition of prescriptive final cover system requirements, as is done in South Africa. The tiered structure attempts to pair the level of environmental risk with the level of protection required. Very small communal landfills are expected to pose lower environmental risk; therefore, no infiltration control system is required. However, medium and large landfills in wet areas pose a significant risk, and a high level of protection is required. Therefore, if a tiered structure appropriate for the conditions found in California is developed, it is expected that its implementation would have a positive environmental impact by prescribing more protective cover systems at sites where the potential for environmental impact is greatest.

With respect to climate issues, California has realized that reliance on low hydraulic conductivity as the sole final cover performance standard can pose problems. For example, allowing heavily compacted low-hydraulic conductivity soil as the final cover in arid regions may allow more infiltration into the waste than the current California requirement allows, even if the hydraulic conductivity of the cover is lower than that of the base liner. Too low a hydraulic conductivity suggests the cover soil is clayey and may be subject to desiccation cracking and increased infiltration in arid climates. Too high a hydraulic conductivity may allow excessive infiltration into the waste. However, if a soil cover is properly designed for hydraulic conductivity and evapotranspiration characteristics (with considerable thickness and low compaction, so as to eliminate brittle failure and enhance root aeration), the soil cover may out perform the prescriptive compacted low-hydraulic conductivity soil cover system.

The use of alternative soil barrier final cover systems in arid climates is currently being studied by the U.S. EPA under the Alternative Cover Assessment Program (ACAP) [Bolen et al., 2001] and the

United States Department of Energy under the Alternative Landfill Cover Demonstration (ALCD) [U.S. DOE, 2000].

- ACAP is establishing field demonstrations at 12 sites nationwide to evaluate the performance of various alternative cover systems over a five-year period. Currently test sections of evapotranspiration cover systems are being installed and monitored nationwide, including several in California.
- ALCD is a five-year (minimum) study of the performance of six test cells (four alternative cover systems and two federal prescriptive cover systems) constructed at a site near Albuquerque, New Mexico.

One anticipated outcome of ACAP is the development of a procedure for designing alternative final cover systems, as well as new methods to regulate these systems.

However, it should be recognized that the South Africa regulations differ from the California regulations in that they do not require the final cover system to be more protective than the base liner system. Unless this California regulation is also changed, a tiered structure would have to be developed for both the base liner and the final cover systems, so that, for example, a less protective cover system would be paired with an equivalently less protective base liner system at small sites. This is a complication of applying a tiered system; other existing landfill regulations would have to be altered to accommodate the addition of a tiered final cover system.

The potential economic impacts of allowing site-specific definition of final cover system requirements are consistent with those discussed in Section 5.3.3. The operational and design impacts are consistent with those discussed in Section 5.3.3.

The prescriptive elements of a graded structure for cover system definition would need to consider existing California requirements for cover system infiltration. Prescriptive definitions for cover system components for each class of landfill should be developed to be compatible with the underlying base containment system.

The results of the cross-media inventory search to classify sites based on rainfall and acceptance rate are discussed in Section 5.3.3. The following table provides a breakdown of environmental performance as it applies to cover performance for the various site conditions.

	Landfill Size											
Climate*	**Community Site (receives less than 27.5 tpd of waste)**			**Small Site (receives 27.5 to 165 tpd of waste)**			**Medium Site (receives 165 to 550 tpd of waste)**			**Large Site (receives more than 550 tpd of waste)**		
	Environmental Performance**											
	GE	GI	SW	GE	GI	SW	GE	GI	SW	GE	GI	SW
Dry	0	7	0	0	3	1	0	3	1	2	6	1
Wet	3	4	2	1	6	4	9	19	10	14	39	20

*Dry"= Desert or high desert: (high desert sites have less than 10 inches of precipitation per year). Wet sites: All other climate designations.

**Environmental performance categories: GE = "Has Gas Enforcement Action," GI = "Has Gas Inspection Report," SW = "Has Surface Water Action."

With respect to cover systems, a review of the cross-media inventory identified 22 landfills where monolithic soil covers have been proposed, though the cross-media inventory does not specify whether these covers were designed to meet the hydraulic conductivity requirement or the through-flow requirement of the regulations. Of these 22 sites, none "have gas enforcement action", six "have gas inspection report," and none "have surface water action."

An Internet literature search of the sources listed in Section 5.1.2 did not identify any documentation of the impact of South Africa's socio-economic- and climate-based structure for defining final cover system requirements. However, one article was identified which addresses the climatic conditions in South Africa and the performance of clay layers in final cover systems [Blight et al., 2003]. This study is ongoing, but preliminary findings suggest that a composite cover of clay, gravel and sand may be most effective in South Africa's arid and semi-arid regions.

5.3.5 Post-Closure Regulations

Site-Specific Considerations for Post-Closure Period (Table 19)

Japan defines the end of the post-closure maintenance period based on the results of groundwater monitoring at the site. The interpreted regulations appear to require that leachate must meet effluent standards for two years and groundwater surrounding the site must not be affected to satisfy monitoring requirements of the post-closure care period. Australia (Victoria) also evaluates the end of the post-closure care period based on the results of site monitoring. By comparison, California requires a minimum 30-year post-closure maintenance period (to be extended as long as wastes pose a threat to water quality, public health and safety, and the environment). The existing California regulations do allow a reduction in monitoring to an annual basis if good performance is demonstrated, but the post-closure care period is not shortened.

Under the existing California regulations, release from post-closure care is considered on a site-specific basis, addressing the potential for the each site to impact the environment in the future. Because a quantifiable definition of the requirement that the site no longer "pose a threat to water quality, public health and safety, and the environment" has not been provided in the California regulations, it is up to the regulators and owners to identify the factors that are relevant to substantiate release from post-closure requirements. The RWQCB have rescinded waste discharge requirements (effectively ending post-closure care) for a number of landfills that have been able to demonstrate to the regulator's satisfaction that the site no longer poses a threat.

The potential environmental impact of defining the end of the post-closure period based solely on the existing quality of leachate and groundwater (as in the Japanese regulations) is that future groundwater conditions are not considered. If the cover system deteriorates and additional leachate is generated, leachate quality may consequently deteriorate, landfill gas generation may increase, and groundwater may be adversely affected. California attempts to minimize the potential for this by requiring a minimum post-closure care period of 30 years, with the idea that the waste will be stabilized in that period and the potential threat to water quality and public health will be lessened. However, the requirement in California for installation of a low hydraulic conductivity or low through-flow cover immediately after the end of waste placement (or within five years with approval from the RWQCB) effectively halts the stabilization of waste, so that waste may not be stabilized after 30 years. Therefore, it is beneficial to incorporate a standard for evaluating the level of degradation of the waste mass as a basis for defining the end of post-closure care.

California's additional requirement that waste "no longer pose a threat to water quality, public health and safety, and the environment" has not been defined in the regulations. This raises the question of how the end of post-closure can be substantiated. The cessation of post-closure means that the landfill need no longer be maintained, and that the owner's demonstration of financial assurance is no longer

required, in spite of the eventual degradation of the containment systems. Therefore, to substantiate the end of post-closure, a demonstration would need to show that unhindered percolation of precipitation through the waste mass will not cause the waste to produce leachate that might adversely impact underlying groundwater if added directly to it (without being delayed by a base liner system). This is similar to the Japanese approach, in that the leachate and groundwater quality are the determining factors for protecting water quality, but this method differs in that it requires the demonstration of future potential to impact the environment. In addition, a successful demonstration would also need to show that the potential for generating landfill gas is non-existent. In other words, a successful demonstration to substantiate the release of a site from post-closure would need to show that the waste contained in the landfill is sufficiently degraded so that it no longer poses a threat to water quality, public health and safety, and the environment.

Adding components to the regulations to consider leachate, landfill gas and water quality performance, as well as the level of degradation of the waste mass, when defining the end of the post-closure period may be environmentally beneficial. These components would allow the end of the post-closure care period to be considered on a site-specific basis, while providing an equitable standard by which to compare all sites.

The potential cost impact of defining the end of the post-closure period based solely on the quality of leachate and groundwater (as in the Japanese regulations) is that the post-closure care period may be substantially shortened for some landfills. However, as discussed above, this method fails to address future degradation. Under California's current approach, no landfill producing truly benign leachate (relative to underlying groundwater quality) where the potential for landfill gas is also non-existent should have a problem making a successful demonstration of no future impact. Landfill owners that have made such demonstrations have realized a substantial cost savings.

It should be recognized that in California, many closed landfills have not reached the end of the 30-year post-closure care period, so that the issue of environmental impact after the end of the 30-year period has yet to be addressed at many sites. Because the existing California regulations do not address specific criteria for releasing sites from the post-closure care period, it is unclear how long beyond 30-years monitoring and maintenance will be required at a particular site. Therefore, the introduction of components to the regulations to address waste stabilization, leachate, landfill gas and water quality in defining the end of the post-closure care period may serve to add consistency in evaluating landfills and has the potential to significantly decrease post-closure costs where it is appropriate.

No technological or operational constraints associated with defining the end of the post-closure period based on leachate and groundwater quality have been identified.

The cross-media inventory generally includes sites that have been operational after 1993, and thus does not include many sites that have begun the post-closure care period. However, 40 of 224 studied California MSW landfills are listed in the database as being "closed," and 36 sites are listed as being "inactive" (pending closure). Six of 224 sites have had their waste discharge requirements rescinded by the RWQCB (meaning that post-closure care has ended). All six of these sites are less than 10 acres in size and are located in the same county. Five are owned by the federal government, and one is owned by a local government. Therefore, of the sites included in the inventory, the six that have been released from post-closure care do not have site characteristics typical of most California MSW landfills. The "typical" California landfill was defined in the Phase 1 report [GeoSyntec, 2003].

An Internet literature search of the sources listed in Section 5.1.2 identified one article that may address the issue of site-specific considerations in evaluating the end of the post-closure care period [Kinoshita, 1993], but it was not available for review.

6 Conclusions and Recommendations

Section 5 presented a detailed discussion of 24 topics which were identified for further discussion (listed in Table 21) and which were selected from the long list of landfill regulations presented in this report (topics listed in Tables 2 and 12). As discussed in detail in Section 5.1.1, these topics were selected because they represent a significant deviation in intent or detail to those enforced in California, or because they are pertinent to current topics being discussed in California. In this section, each of these regulations will be further discussed to evaluate their applicability to California.

Based on this review of regulations from the eight selected states and five selected countries, some general observations have been made.

- In general, the California regulations appear to be less specific than the regulations from the eight selected states. This lack of specificity, especially with regard to design and construction elements of the regulations, provides more flexibility. This seems appropriate in a state such as California, which has diverse climate, population density, socio-economic conditions, land use, geology, and topography (collectively referred to as the physical and social setting). All of the states reviewed are more homogeneous in one or more of these respects, which may allow their landfill regulations to be more specific.

- In general, the California regulations appear to be similar to the five countries reviewed in that they are all attempting to accommodate highly variable site conditions. Of the five regulatory topics from countries discussed in Section 5, two pertained to prescriptive tiered regulations that address site-specific conditions such as climate and size. Accounting for site-specific conditions allows one set of regulations to govern a heterogeneous population, while allowing a tailored approach to providing environmental protection. Some regulations from the five countries generally include more flexibility in the selection of landfill sites and prescribe a wider range of options for base liner components based on site-specific conditions.

- In general, California appears to have found a balance between flexibility and specificity appropriate to the heterogeneity of the state. However, the lack of specificity in some regulations can result in different interpretations being drawn by regulatory agencies in different areas of the state for similar site conditions. Without jeopardizing the flexibility currently allowed in California, regulatory clarity could be provided to help with interpretation where warranted. It may also be appropriate to develop an equitable standard by which certain aspects of landfill design and operation may be evaluated, such as a tiered approach for base liner requirements for different site-specific conditions or a quantitative basis for evaluating the end of post-closure.

With these general observations in mind, a brief assessment of the applicability of each of the 24 regulatory topics in California has been developed, with consideration given to the variability of the physical and social setting across the state. These topics were discussed separately in Section 5 based on whether they were taken from state regulations or country regulations to allow easy cross-reference with the summary tables. In this section, state and country regulations are combined to provide an integrated discussion of regulations related to individual categories, such as siting requirements.

6.1 Regulations for Special Handling of Waste

Waste Pre-Processing: It is expected that introducing a requirement for pre-processing and/or pre-treatment of waste into the California regulations would have a significant benefit for both environmental protection and waste handling and disposal costs. The EU requirement for waste pre-processing has been praised as a significant step toward developing a sustainable waste management cycle. However, the specific benefits of various methods of pre-processing (summarized in Section 5

and discussed in detail in the Landfill Facility Compliance Study's Task 7 emerging technologies report [GeoSyntec, 2003a]), especially with respect to their applicability to California's physical and social setting and the associated cost implications, should be thoroughly investigated to enable the development of an appropriate regulation for California. It is recommended that a regulatory requirement for the pre-processing and/or pre-treatment of waste be considered for implementation in California, if a detailed cost-benefit analysis indicates that it is appropriate.

6.2 Siting Regulations

Several topics were discussed in Section 5 with respect to siting requirements. These topics have varying degrees of applicability to California landfill regulations and will be discussed separately in this section.

- **Separation From Groundwater**: Because almost 75 percent of the existing active landfills in California have groundwater shallower than 100 feet, implementation of a requirement for siting landfills only at sites with groundwater greater than 100 feet below ground surface seems impractical, especially in the northern half of the state where groundwater is generally shallow. It is expected that the environmental benefit would be outweighed by additional costs and environmental barriers associated with hauling waste to remote sites. No change to the California regulations is recommended.

- **Distance From Wetlands**: The applicability of a more stringent requirement for the siting of landfills near wetlands should be based on the need to protect California's wetlands. The actual environmental impact of existing landfills that comply with California's current siting regulations on California's wetlands should be thoroughly reviewed prior to the development of new regulations restricting landfill siting. It is recommended that more stringent requirements for siting near wetlands only be considered for adoption into the California regulations if it is warranted by the results of that review.

- **Distance From Water Supply Wells**: The applicability of a more stringent requirement for the siting of landfills near water supply wells should be based on the perceived need to protect California's water sources. However, distance may not be the most appropriate parameter for controlling the affect of a landfill on the quality of a water supply well because the impact is also dependent on the permeability of the strata, the direction and rate of flow, and the depth to the aquifer. The actual environmental impact of existing landfills (where the prescriptive minimum base liner system has been installed) on water supply wells should be thoroughly reviewed prior to the development of new regulations restricting landfill siting. It is recommended that more stringent requirements for siting in proximity to water supply wells be considered for adoption into the California regulations only if they are warranted by the results of that review.

- **Site-Specific Siting Criteria:** Evaluating criteria for landfill siting based on the physical and social setting of the site would allow more flexibility in selecting landfill sites based on environmental protection considerations appropriate for that area, and would give more authority to the local regulatory agency in directing their jurisdiction. Different standards for siting may be developed in one part of the state than another, so that the landfill industry may grow faster in one part of the state than another based on less stringent siting criteria. In addition, site-specific siting criteria are currently considered under the CEQA process. Therefore, changing the landfill regulations to allow for site-specific siting criteria may not be necessary, and is not recommended.

6.3 General Design Regulations

Three topics were discussed in Section 5 with respect to general design requirements. These topics have varying degrees of applicability to California landfill regulations and will be discussed separately in this section.

- **Design Requirements and Submittals:** Because the current state –of –the practice in California allows for additional submittals to be requested by the permitting agency when it is warranted by site-specific conditions, it may not be an improvement to the landfill regulations to require more design submittals. In addition, the development of general guidance documents for landfill design and construction, such as have been developed in several other states, may be an appropriate alternative to imposing new regulations. Guidance documents can help provide consistency and reliability across the state, and since they are not enforceable, they may be adjusted to account for site-specific conditions. Therefore, it is recommended that non-enforceable general guidance documents be developed in lieu of changing the existing California landfill regulations. This recommendation would not require any change to the existing California landfill regulations.

- **Liner Performance Evaluation:** Existing California regulations do not require a performance evaluation for the prescriptive single composite liner (or engineered alternatives), but allow permitting agencies to require one. This approach seems to be appropriate for California, given the variability of both the physical setting and the potential environmental impact of landfills across the state. Therefore, it is not recommended that liner performance evaluations be required in the California landfill regulations. However, if the recent trend toward requiring liner performance evaluations continues, a prescriptive standard for evaluating landfill performance should be developed, if feasible, and criteria for acceptable performance should be defined.

- **Surface Water Design Storm Event:** California's requirement of a 100-year, 24-hour design storm is more restrictive than regulations in the eight other states and requirements by the federal government. California's requirement provides more protection of the environment and reduces system maintenance costs. California's requirement predates the Subtitle D regulations (it is in the 1984 Chapter 15 rulemaking[‡]). California is known for high-intensity, short-duration storms. Since 1950, all 58 California counties have been declared flood disaster areas no fewer than three times [California Department of Water Resources, 2003]. Also, the impacts of overflow listed under Section 5.2.2 "Surface Water Design Storm Requirements" provide additional reason to have the 100-year storm requirement. Therefore, no change to the California landfill regulations is recommended.

6.4 Base Liner System Regulations

Four topics were discussed in Section 5 with respect to base liner requirements. These topics have varying degrees of applicability to California landfill regulations and will be discussed separately in this section.

- **Natural Geologic Liner or Single Clay Liner:** Prior to Subtitle D and Resolution 93-62, the Water Board regulations allowed for a single clay liner or natural geologic liners for Class III landfills. This was changed, in part, to comply with the minimum standards of Subtitle D. Current California landfill regulations allow certain sites to be exempted from Subtitle D requirements based on their low waste acceptance rate and continued lack of impact on groundwater. However, for all other landfills, California regulations do not allow natural geologic liners because "Solid Waste Assessment Test Reports…have shown that releases of leachate and gas from MSW landfills that are unlined are likely to degrade the quality of underlying groundwater" [SWRCB, 1993]. Likewise, single clay liners are not allowed because they "will only delay, rather than preclude, the onset of leachate leakage" [SWRCB, 1993]. However, no liner system (even with a geomembrane component) is completely leak-proof.

[‡] 23 CCR, Chapter 15 refers to regulatory requirements that pertained to MSW landfills. In 1997, these regulations were moved to 27 CCR, Division 2.

Given the large portion of the state with low precipitation, it may be appropriate to consider single clay or natural geologic liners at sites in those areas where the anticipated volume of leachate is low. However, a natural geologic liner or a single clay liner would be inherently less protective than a liner system that also incorporates a geomembrane. Therefore, while a natural geologic or single clay liner might be shown to be sufficiently protective, it would still be less protective than the current prescriptive composite liner.

It should also be recognized that the trend in the state is toward fewer, larger landfills with a greater potential for impacting the environment. Small community landfills with low potential for impacting the environment are being closed. It may not, therefore, be in line with the current trends in waste management to open up the use of clay liner systems or natural barrier liner systems to more sites than are currently allowed because they may be less protective than the current prescriptive standards. No change to the existing California landfill regulations is recommended.

- **Design and Construction of Liner Components (Clay and Geosynthetics):** While imposing design and construction standards in the regulations may provide consistency and reliability in liner systems, the efficiency and performance of some sites may be hampered. Because of the variability in site conditions across the state, it may not be appropriate to stipulate specific design and construction criteria for all sites. The development of non-enforceable general guidance documents for liner design and construction, such as have been developed in several other states, may be an appropriate alternative to imposing new regulations because they can provide consistency and reliability across the state. Since they are not enforceable, they may be adjusted to account for site-specific conditions. Therefore, it is recommended that non-enforceable general guidance documents be developed in lieu of changing the existing California landfill regulations.

- **Double Liner Systems:** Recent studies [U.S. EPA, 2002] have found that Subtitle D compliant single composite liner systems can have a very high hydraulic efficiency and are capable of preventing adverse impacts on the environment. Existing California regulations do not include any provisions for when a double liner may be required, but allow permitting agencies to require one. This approach seems appropriate for California, given the variability across the state of both the physical setting and the potential impact of landfills on the environment. No change to the existing California landfill regulations is recommended. However, if the recent trend of permitting agencies considering double liners continues, a prescriptive standard for evaluating landfill performance should be developed, if feasible, and criteria for acceptable performance should be defined in the regulations.

- **Multiple Prescriptions for Base Liners Based on Site Conditions:** Providing a tiered structure for prescriptive base liner requirements based on the physical and social setting of the landfill site may be an appropriate alternative to California's current prescriptive single composite liner requirement. Defining the appropriate prescriptive liner system based on the physical and social setting of the site would allow site-specific conditions to be considered and would provide efficiency in the design and installation of liners. It would also give more direction to the local agency in regulating their jurisdiction, while still allowing the flexibility to require more protective systems if warranted.

  The concept that different levels of protection may be appropriate at different landfill sites is widely acknowledged. Current Subtitle D regulations allow for the exemption of small landfills based on their low waste acceptance rate and low potential to impact groundwater. Findings from the Task 3, Landfill Facility Compliance Study Phase I report [GeoSyntec, 2003] similarly suggest that small, rural, unlined landfills in dry climates are less likely to be in the status "In Corrective Action" than other landfills. By contrast, the North Coast and Central Valley RWQCBs have been

requiring liner performance evaluations to demonstrate the effectiveness of the prescriptive single composite liner system, and in some cases have required the installation of a double composite liner system.

To apply this type of regulatory structure to the existing California landfill regulations, a further breakdown of landfill categories would need to be defined based on the range of social and physical characteristics found across the state. In addition, the prescriptive liner requirements for each of the categories would need to be defined so that each liner requirement will be appropriately protective of the environment of California. It is recommended that a tiered structure for multiple prescriptive base liner systems based on site conditions be considered for application to California landfill regulations if it can be shown to be more environmentally protective than the current regulatory system.

6.5 LCRS Regulations

Three topics were discussed in Section 5 with respect to LCRS requirements. These topics have varying degrees of applicability to California landfill regulations and will be discussed separately in this section.

- **LCRS Design Specifications:** As was discussed in Section 5.2.4, existing California regulations for LCRS design allow "no build-up of hydraulic head" on the base liner, which, if taken literally, is impossible to achieve unless no leachate is being generated in the cell. Because for practical purposes California's regulation has generally been interpreted to allow no build-up greater than 12 inches, or greater than the thickness of the LCRS layer, whichever is less, the intent of the regulation to minimize the potential for liner leakage has been achieved, and no changes to the existing regulations are recommended.

- **Secondary LCRS (LDS):** The recommendation for the LDS is similar to that presented above for double liner systems since an LDS is included in the design of double liners. Recent studies [U.S. EPA, 2002] have found that Subtitle D-compliant single composite liner systems can have a very high hydraulic efficiency and are capable of preventing adverse impacts on the environment. However, the installation of an LDS below a single composite liner system may be appropriate for some site-specific conditions. Existing California regulations do not include any provisions for when an LDS may be required, but allow permitting agencies to require one. This approach seems to be appropriate for California given the variability across the state of both the physical setting and the potential impact of landfills on the environment, and no change to the existing California landfill regulations is recommended. However, if LDSs are routinely required by the permitting agencies, a prescriptive standard for evaluating landfill performance should be developed, if feasible, and criteria for acceptable performance should be defined.

- **Leachate Recirculation:** The additional requirements specified by other states with respect to leachate recirculation may be appropriate in their respective states, where landfill conditions may be consistent across the state or other more restrictive regulations have been applied which require additional constraints on leachate recirculation, and blanket specifications are warranted. However, in California the decision to allow leachate recirculation has been the responsibility of the RWQCB. This approach is recommended for California, given the variability across the state of both the physical setting and the potential impact of landfills on the environment. Using this approach, additional constraints, as appropriate to address site-specific conditions, are applied by the RWQCB in their decision to allow leachate recirculation. No changes to the existing California landfill regulations are recommended.

6.6 Final Cover System Regulations

Multiple Prescriptions for Final Covers Based on Site Conditions: Providing a tiered structure of multiple prescriptive final cover systems based on the configuration and physical and social setting of the landfill site may be an appropriate alternative to California's all-inclusive requirement. California's existing regulations accommodate climatic impacts by allowing either a prescriptive final cover (designed for maximum allowable hydraulic conductivity) or a performance-based final cover (designed for maximum allowable through-flow). Even though the existing regulations do not directly consider the impact of any site conditions other than climate, they do allow flexibility by the regulators to consider site-specific characteristics during the design approval process. Therefore, no significant environmental protection benefit is anticipated from the addition of a more complicated tiered structure of prescriptive final cover systems. No changes to the existing California landfill regulations are recommended.

6.7 Post-Closure Regulations

Two topics were discussed in Section 5 with respect to post-closure requirements. These topics have varying degrees of applicability to California landfill regulations and will be discussed separately in this section.

- **Post-Closure Land Use:** Several states stipulate specific exclusions for post-closure land use activities. However, because of the variability in site conditions and social setting of landfills across the state, it may not be appropriate to stipulate all-encompassing land use exclusions criteria. It is recommended that post-closure land use recommendations be set forth in non-enforceable general guidance documents without making a change to regulations. No changes to the existing California landfill regulations are recommended.

- **Site-Specific Post-Closure Period:** Two of the countries included in this study specifically define the end of the post-closure care period based on site-specific consideration of environmental performance. California's current regulations and statutes state that a landfill operator may be released from post-closure maintenance after a minimum period of 30 years, upon demonstration to and approval by regulatory agencies that the waste in the landfill no longer poses a threat to groundwater quality, public health and safety, and the environment. Although there are no definitive criteria to pre-determine the end of the post-closure maintenance period, an operator can, at any time, provide evidence to document that post-closure maintenance should be discontinued because the waste no longer poses a threat. Alternatively, even if the operator cannot provide sufficient evidence to discontinue post-closure maintenance, the operator might still be able to justify a significant decrease in the level of post-closure maintenance, thus lowering post-closure maintenance costs.

  Adding components to the regulations to consider leachate quality, landfill gas and water quality performance, and the level of degradation of the waste mass when determining when to end the post-closure period would allow the end of the post-closure care period to be considered on a site-specific basis, while providing an equitable standard by which to compare all sites. If prescriptive standards are added for (1) leachate quality, (2) landfill gas quality, (3) water quality, and (4) level of waste degradation, to evaluate the potential future environmental impact of a site, the current regulatory 30-year minimum period could stay the same.

  There are several ongoing research projects looking at the concept of ending post-closure maintenance, but this work is very preliminary. One difficulty in developing standards is that dry tomb landfills (favored by Subtitle D) indefinitely suspend and/or retard the decomposition process, such that a breach in containment (caused, for example, by an extreme climate or earthquake event, inappropriate land use, or long-term aging of geosynthetics) could trigger

uncontrolled production and release of landfill gas and leachate, as well as public contact with waste. Should these research projects come up with standards that can effectively determine when the waste in Subtitle D landfills no longer poses a threat, then California should consider these standards and pursue the development of quantifiable standards for defining the end of post-closure, if the standards can be shown to achieve greater environmental protection than current regulations.

6.8 Groundwater Monitoring Regulations

Three topics were discussed in Section 5 with respect to groundwater monitoring regulations. These topics have varying degrees of applicability to California landfill regulations and will be discussed separately in this section.

- **Concentration Limits in Groundwater:** New Mexico allows different concentration limits for triggering assessment/evaluation monitoring than for triggering corrective action. This type of regulation is not appropriate for application in California because California's water standard is more strict than in New Mexico. If New Mexico's concentration limit methodology were adopted, its water standard would also need to be adopted, and the California Water Code would also have to be amended to allow low-concentration release to remain uninvestigated. No changes to the existing California regulations are recommended.

- **Groundwater Monitoring System Requirements:** Adopting a requirement for a minimum number of groundwater monitoring wells, such as is required in Pennsylvania and West Virginia, is not expected to provide any substantial environmental or economic benefit. No changes to the existing California regulations are recommended.

- **Corrective Action Criteria:** No significant environmental or economic benefit, beyond those provided by California's current regulations, has been identified to support the incorporation of a range of corrective actions for groundwater impacts of different severity. No changes to the existing California regulations are recommended.

6.9 Landfill Gas Control Regulations

Performance Requirements: The applicability of a more stringent requirement for the concentration of explosive gases at the facility boundary should be based on the need for additional protection of human health and the environment. The actual environmental impact of existing landfills that comply with California's current landfill gas control regulations should be thoroughly reviewed prior to the development of new regulations restricting explosive gases. It is recommended that more stringent requirements for explosive gases only be considered for adoption into the California regulations if it is warranted by the results of that review.

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Tables

Notes and Abbreviations

Note 1: The symbol "--" used in these tables denotes that a category is either not applicable because of a related restriction, or that no discussion of the category was identified in the regulations.

Note 2: The term "permeability" used in some regulations is interpreted to mean "coefficient of permeability," which has the appropriate units (length / time).

ARB = Air Resources Board (Calif.)	M = meter
BPEM = Best Practice Environmental Management (Victoria, AU)	MCL = maximum contaminant level (for drinking water)
CAL = corrective action limit	Mg = megagram
CAP = corrective action program	min. = minimum
CCL = compacted clay liner	MPE = maximum probable earthquake
CCR = California Code of Regulations	MSW = municipal solid waste
CFR = Code of Federal Regulations (U.S.)	MSWLF = municipal solid waste landfill
CLGB = concentration limit greater than background	NJAC = New Jersey Administrative Code
CQA = construction quality assurance	NMAC = New Mexico Administrative Code
CSR = Code of State Rules (West Virginia)	NMOC = non-methanogenic organic compound
DMP = detection monitoring program	NYCRR = New York Code of Rules and Regulations
DNR = Department of Natural Resources (Wisconsin)	O_2 = oxygen
EA = Enforcement Agency (Calif.)	PI = plasticity index
EMP = evaluation monitoring program	POC = point of compliance (for monitoring standards)
EPA = Environmental Protection Agency (U.S.)	Ppm = parts per million
EU = European Union	ppmv = parts per million by volume
FAA = Federal Aviation Administration	RWQCB = Regional Water Quality Control Board (Calif.)
GCL = geosynthetic clay liner	RCRA = Resource Conservation and Recovery Act (U.S.)
GM = geomembrane	SWRCB = State Water Resources Control Board (Calif.)
H:V = horizontal to vertical	TAC = toxic air contaminant
HDPE = high density polyethylene	TOC = total organic compounds
k = hydraulic conductivity/permeability	vol. = volume
LCRS = leachate collection and removal system	WAC = Washington Administrative Code
LDS = leak detection system	WMP = Draft Waste Management Policy (Victoria, Australia)
LEL = lower explosive limit	WVDOEP= West Virginia Department of Environmental Protection
LL = liquid limit	

Table 1. State Regulatory Agencies, Websites, and Regulations

State	Regulatory Agency	Website	Regulation
California	California Integrated Waste Management Board California State Water Resources Control Board California Air Resources Board	www.ciwmb.ca.gov www.swrcb.ca.gov/ www.arb.ca.gov	SWRCB Res. 93-62 CCR, Title 27 (27 CCR), Division 2
Delaware	Delaware Department of Natural Resources and Environmental Control	www.dnrec.state.de.us	Del. Code, Title 7 (7 Del. C.), Chapter 60
New Jersey	New Jersey Department of Environmental Protection, Division of Solid and Hazardous Waste	www.state.nj.us/dep/dshw/	NJAC, 7:26
New Mexico	The New Mexico Environment Department	www.nmenv.state.nm.us/	NMAC, Title 20, (20 NMAC), Chapter 9, Part 1
New York	New York State Department of Environmental Conservation	www.dec.state.ny.us/website/dshm/	6 NYCRR Part 360
Pennsylvania	Pennsylvania Department of Environmental Protection	www.dep.state.pa.us/	Pennsylvania Code, Title 25, Article VIII, Chapter 273
Washington	Washington Department of Ecology	www.ecy.wa.gov/ecyhome.html	WAC, Chapters 173–351
West Virginia	West Virginia Department of Environmental Protection	www.dep.state.wv.us/	CSR, Title 33 (33 CSR)
Wisconsin	Wisconsin Department of Natural Resources	www.dnr.state.wi.us/	Chapter NR 504

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Table 2. Comparison of States: Regulatory Topics Included in Tables 3 Through 10

Siting (Tables 3a, 3b, and 3c)
Separation Between Waste and Highest Groundwater
Minimum Distance
Allowable Alternatives
Type of Subgrade and Separation From Bedrock
Material Underlying Landfill Site
Separation Between Top of Bedrock Surface and Bottom of Liner
Horizontal Distance From Floodplain, Wetlands, and Water Supply Wells, Separation From Aquifer, and Distance From Airports
Distance From Floodplain
Distance From Wetlands
Distance From Water Supply Wells
Proximity to Aquifer
Distance From Airports
General Design Requirements (Tables 4a and 4b)
General Design Requirements—Summary
Checklist of Required Design Elements, Analyses and Calculations
Required Analyses and Design Calculations
General Design Requirements—Liner Performance, Surface Water, and Stability
Liner Performance Evaluation
Conditions When Required
Details of Liner Performance Requirements
Surface Water Drainage System
Design Storm
Slope Stability Analyses
Slope Stability to Incorporate Containment System?
Acceptable Factor of Safety
Design Seismic Event
Allows Estimation of Seismic Movement?
Base Liner System (Tables 5a to 5d)
Base Liner System—General
Permitted Liner Types
Type of Liner
Base Liner System—Single Clay Liner or Natural Geologic Liner
Minimum Thickness
Maximum Hydraulic Conductivity/Permeability
Condition When Allowed
Base Liner System—Single Composite Liner
Definition

Upper Component
Lower Component
Other Component
Alternatives
Geosynthetic Component
Construction Issues
Other Factors
Clay Component
Thickness
Maximum Hydraulic Conductivity/Permeability
Construction Issues
Base Liner System—Double Liners (Including Double Composite Liners) (General)
Conditions When It Must Be Used
Configuration
Primary Liner
Secondary Liner
Middle Component
Alternatives Reference
Construction and Design Requirements
Leachate Collection and Recovery System (Tables 6a to 6c)
Leachate System—Primary LCRS
Minimum Layer Thickness
Minimum Hydraulic Conductivity/Permeability
Maximum Allowable Head on Liner
Design Flow
Alternatives Allowed?
Slope Requirements
Pipe Specifications
Pipe Wall Thickness
Other Design Factors
Leachate System—Secondary LCRS
Minimum Layer Thickness
Minimum Hydraulic Conductivity/Permeability
Maximum Allowable Leakage
Design Flow
Alternatives Allowed?
Slope Requirements
Pipe Specifications
Pipe Wall Thickness
Other Factors

Leachate System—Leachate Recirculation
Recirculation Allowed?
Required Liner System to Allow Recirculation
Other Requirements
Cover System (Tables 7a to 7c)
Final Cover System—General
Minimum Requirements
Requires Composite Final Cover
Requires Final Cover to Have Hydraulic Conductivity/Permeability Less Than or Equal to That of Liner/Subsoil
Requires Synthetic in Final Cover, If Base Liner Has Synthetic
Allows Alternative
Final Cover System—Components
Top Soil
Vegetative Cover (in addition to top soil)
Drainage Layer
Infiltration Control—Geosynthetic
Infiltration Control—Soil
Are Both Required?
Gas Venting Layer
Foundation/Grading Layer
Final Cover System—Application
Days Since Waste Placement Before Final Cover Must Be Placed
Maximum Slope
Minimum Slope
Requirement for Benches
Other Requirements
Allows Alternate Cover
Post-Closure Maintenance Requirements (Table 8)
Minimum Post-Closure Maintenance Period
Reporting and Site Review
Systems Maintenance and Operation
Monitoring Requirements
Financial Assurance
Post-Closure Land Use Restrictions
Groundwater Monitoring Regulations (Table 9)
Applicability
Required programs
Water Quality Protection Standard (Water Standard)
Constituents of Concern

Concentration Limits
Point of Compliance (“POC” for Monitoring)
Compliance Period
General Water Quality Monitoring and System Requirements
Detection Monitoring Program (DMP)
Evaluation monitoring program (EMP)
Correction action program (CAP)
Landfill Gas Control Regulations (Table 10)
Applicability Trigger
Compliance Plan Schedule
Compliance Deadline
Performance Requirements
System Design and Testing Requirements
Monitoring Requirements
Record-Keeping Requirements
Reporting Requirements

Table 3a. Comparison of States: Siting—Separation Between Waste and Highest Groundwater

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Regulation Section									
--	27 CCR, Sec. 20240 (c) and definition of "underlying groundwater" in Sec. 20164.	7 Del. C., Sec.5.C.1(c)	NJAC, 7:26-1A.7(b)4.xii	20 NMAC, Chap. 9, Part1, Subpart III, Sec. 302.A.2.	6 NYCRR, Sec. 360-2.13(d)	Title 25,Pennsylvania Code, Chap. 273.252 (b)	Chapter 173-351-140(a), WAC	33 CSR, 1-4.5.d.2.A and B	NR 504.06(2)(a)(4)(b)
Minimum Distance									
--	5 ft (includes water level rise due to capillary forces).	5 ft	For "stable low permeable formation," 5 ft of soil with k $\leq 10^{-6}$ cm/s between bottom of liner and aquifer. For all other landfills, depth to seasonally high groundwater from the top of foundation shall be at least 3 ft.	100 ft	5 ft (leachate lines and appurtenances outside the liner do not need to meet this).	"The bottom of subbase of the liner system cannot be in contact with the seasonal high water table or perched water table without the use of groundwater pumping systems."	10 ft (5 ft if a hydraulic gradient control system, or equivalent, is installed – see below).	4 ft for seasonal high and 8 ft for permanent groundwater table.	10 ft (except for zone-of-saturation landfills).
Allows Alternative?									
Yes	Yes	Yes	Yes	--	Yes, upon demonstration that there will be no adverse impact.	No, "The regional groundwater table may not be artificially lowered."	Yes	Yes	Yes. Zone-of-saturation landfills can have base grade below groundwater table.
Alternative Methods									
Only as specifically allowed in any given section, based upon state agency findings	Engineered alternatives (to a prescriptive standard).	A "more stringent liner system design which provides enhanced protection of ground water."	"The depth to or within a perched water table may be less than five feet if this level can be cut-off by passive means, such as a cut-off wall or trench."	--	Additional "drainage systems" during construction, until the hydrostatic pressures are equalized by weight of liner system and/or waste."	--	A hydraulic gradient control system or equivalent to control groundwater fluctuations and maintain 5 foot separation between controlled seasonal high level of groundwater and the bottom of the lowest liner.	Drainage systems to maintain 4 ft separation limited to drain tile, piping, and french drains.	Zone-of-saturation landfills for sites with fine-grained subgrade material (NR504.06(4)

Table 3b. Comparison of States: Siting—Type of Subgrade and Separation From Bedrock

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Material Underlying Landfill Site									
Regulation Section									
--	--	--	NJAC, 7:26-2A.6(e)1	--	6 NYCRR Sec. 360-2.12(a) (1) (v)	Title 25,Pennsylvania Code § 273.253 (a)	--	33 CSR1-4.5.d.3.A.1-5	--
Description									
--	--	--	When bedrock is at or near surface and serves as direct source of water supply, landfill must have a double composite liner.	--	"unconsolidated deposit" [most likely to minimize migration of contaminants from the landfill into underlying bedrock] – either natural, or constructed to be at least 20 ft thick.	Subbase layer below base liner: min. 6 in. thick, 95% of std. Proctor and $k \leq 1 \times 10^{-5}$ cm/s. Slope between 2% and 33%.	--	Subbase layer below base liner: min 6 in. thick, 95% of std. Proctor and 3 to 5% of optimum, with $k \leq 1 \times 10^{-6}$ cm/s and slope of at least 2%.	--
Separation Between Top of Bedrock Surface and Bottom of Liner									
Regulation Section									
--	--	--	NJAC, 7:26-2A.6(e)1	--	6 NYCRR Sec. 360-2.13(e)	--	--	33 CSR1-4.5.d.2.C	NR 504.06(2)(a)(4)(c)
Distance									
--	--	--	--	--	10 ft	--	--	4 ft	10 ft

Table 3c. Comparison of States: Siting—Horizontal Distance From Floodplain, Wetlands, and Water Supply Wells, Separation From Aquifer, and Distance From Airports

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Distance From Floodplain									
For landfills located within a 100-year floodplain, must demonstrate that it will not restrict flow of the 100-year flood, reduce temporary water storage capacity, or result in washout of solid waste.	Includes by reference 40 CFR, 258.11& 258.16.	Not located within a 100-year floodplain.	Pursuant to the State Flood Hazard Area Control Act, N.J.S.A. 58:16A-50 et seq.	Not located within a floodplain.	For landfills located within a 100-year floodplain, must demonstrate that it will not restrict flow of the 100-year flood, reduce temporary water storage capacity, or result in washout of solid waste.	Not located within a floodplain.	For landfills located within a 100-year floodplain, must demonstrate that it will not restrict flow of the 100-year flood, reduce temporary water storage capacity, or result in washout of solid waste.	For landfill located within 100-year floodplain, must demonstrate that does not restrict flow, reduce water storage capacity, or result in washout of solid waste.	Not within a floodplain.
Distance From Wetlands									
Not located in wetlands, unless demonstrate no adverse effect.	Includes by reference 40 CFR, 258.12 in SWRCB Res. 93-62	Not located in an area that may degrade wetlands, unless impact is mitigated.	Pursuant to the Wetlands Coastal Resource and Development Policies, NJAC, 7:7E.	Not located within 500 ft of wetlands.	Not located in wetlands, unless permitted by the Army Corps of Engineers and demonstrated that it will not degrade the wetlands.	Not located within 300 ft of exception value wetland (defined in § 105.17) or within 100 ft of other wetlands.	Not located in wetlands, unless demonstrated that landfill will not degrade wetlands.	Not located within 300 ft of wetlands.	No significant adverse impact on wetlands as provided in Ch. NR 103.
Distance From Water Supply Wells									
--	--	Not within "the wellhead protection area of public water supply well or well field."	--	1,000 ft of well that pumps ≥ 100 gpm 350 ft of well that pumps < 100 gpm.	--	Within ¼ mil upgradient and within 300 ft downgradient of public or private water source.	1,000 ft	1,200 ft	1,200 ft
Proximity to Aquifer									
--	--	Not within "a formally designated aquifer resource protection area."	--	--	Not permitted over primary water supply aquifer or principal aquifer. 6NYCRR Sec. 360-2.12(c)(1).	--	Not permitted over a designated sole source aquifer.	--	--

Table 3c (continued). Comparison of States: Siting—Horizontal Distance From Floodplain, Wetlands, and Water Supply Wells, Separation From Aquifer, and Distrance From Airports

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Distance From Airports									
Landfill units within 10,000 ft of airport used by jet aircraft or within 5,000 ft of airport used by propeller aircraft must demonstrate that units do not pose a bird hazard. Landfill units proposed within 5 miles of runway end must notify the airport & FAA.	Same as federal.	Not permitted within 10,000 ft of airport used by jet aircraft or within 5,000 ft of airport used by propeller aircraft unless a waiver is received from the FAA.	Landfill units within 10,000 ft of airport used by jet aircraft (runway length >3,000 ft) or within 5,000 ft of airport used by propeller aircraft (runway length <3,000 ft) must submit a bird deterrent plan. Landfill units proposed within 5 miles of runway end must notify the airport & FAA.	No MSW landfill units permitted within the distance from an airport set by the FAA.	Landfill units with putrescible waste must not be located within 10,000 ft of airport used by jet aircraft or within 5,000 ft of airport used by propeller aircraft. Landfill units proposed within 5 miles of runway end must not pose a bird or obstruction hazard per FAA. The final elevation of any landfill must not be more than 200 feet above the highest pre-existing land elevation, unless approved by FAA.	Not permitted within 10,000 ft of airport used by jet aircraft or within 5,000 ft of airport used by propeller aircraft. Not permitted in areas where landfill operation would obstruct air navigation per 14 CFR 77.23(a)(5).	Same as federal.	Not permitted within 10,000 ft of airport used by jet aircraft or within 5,000 ft of airport used by propeller aircraft or in other areas where a bird hazard to aircraft would be created, unless it is demonstrated that a bird hazard to aircraft is not created.	Same as federal.

Table 4a. Comparison of States: General Design Requirements—Summary

	Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Checklist of Required Design Elements, Analyses, and Calculations										
Regulation Section	--	27 CCR, 21710 et seq.; 27 CCR, 21600	--	NJAC, 7:26-2A.5(a)	--	--	--	173-351-490 & 730	--	--
Is there a list?	No	Yes, for ROWD and RDSI.	Yes	Yes	Yes	Yes	No	Yes	No	No
Required Analyses and Design Calculations										
Geotechnical Report	No	Yes	No	Yes	No	No	Yes	No	No	No
Geologic Map and Report	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Slope Stability	No	Yes	No	Yes	No	Yes	No	No	No	No
Liner Stress	No	No	No	No	Yes	No	No	No	No	No
Anchor Trench	No	No	No	Specifies dimensions	Yes	No	No	No	Specifies dimensions	Yes
Leachate System	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Groundwater Transport Model	No	No	No	Yes	No	No	No	Yes	No	No
Run-On and Run-Off System	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gas System	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 4b. Comparison of States: General Design Requirements—Liner Performance, Surface Water, and Stability

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Liner Performance Evaluation									
Regulation Section									
40 CFR §258.40(a)(1)	SWRCB Res. No. 93-62	--	NJAC, 7:26-2A.6(f)	--	--	--	173-351-300 (2)(a)(iii)	--	--
Conditions When Required									
When not using prescriptive composite base liner design.	Same as federal.	--	For all natural geologic, single clay and single composite liner systems. Double composite systems are exempt.	--	--	--	For alternatives to the prescriptive single composite liner.	--	--
Details of Liner Performance Requirements									
Do not exceed MCLs at the POC through to end of Post-Closure Period (30 yrs.).	Same as federal and must contain waste at least as well as prescriptive composite design.	--	Site-specific geology, 3-D transport model.	--	--	--	HELP model, or equivalent.	--	--
Surface Water Drainage System									
Regulation Section									
40 CFR, Sec. 258.26	27 CCR, Sec. 21090(b)(3) & 20365	7 Del. C., Sec. 5.F.1(2)	NJAC, 7:26-2A.7(g)1	20 NMAC9.1, Sec. 402E(2)	6 NYCRR, Sec. 2.15(d)(2)	Title 25, Pennsylvania Code, Sec. 273.242	173-351-200 (7)(a)(ii), WAC	33 CSR,1-4.5.b.4.A	NR 504.09 (1)(d)
Design Storm									
25-year, 24-hour	100-year, 24-hour	25-year, 24-hour	25-year, 24-hour	25-year, 24-hour	25-year, 24-hour	25-year, 24-hour	25-year, 24-hour	25 year, 24-hour	25-year, time of concentration event for drainage features 25-year, 6-hour event for sediment control measures.

Table 4b. (continued) Comparison of States: General Design Requirements—Liner Performance, Surface Water, and Stability

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Slope Stability Analyses									
Regulation Section									
--	Title 27 CCR §21750(f)(5) and §20310(g).	Sec. 5.C.2 (a)	NJAC, 7:26-2A.7A(b)3(i)	20 NMAC, 9.1, Sec. 273.302 (a) (9)	6 NYCRR, Sec. -2.7(b)(6)	--	WAC 173-351-130 (6)	33 CSR,1-3.2 m	NR 504.004 (3)(h)
Slope Stability to Incorporate Containment System?									
--	Yes	--	Yes	--	Yes	--	--	--	--
Acceptable Factor of Safety									
--	1.5 under dynamic condition, or estimate seismic movement (see below).	--	1.5 under static condition.	--	2.0 for bearing capacity and settlement 1.25 for structural design of components 1.5 for final cover 1.0 under seismic condition.	--	--	--	--
Design Seismic Event									
Maximum acceleration with probability ≥ 90% of not being exceeded in 250 yrs from a map or design earthquake from a site-specific analysis.	MPE (“the maximum earthquake that is likely to occur during a 100 year interval” from a site-specific analysis).	Maximum acceleration with probability ≥ 90% of not being exceeded in 250 yrs.	Maximum acceleration with probability ≥ 90% of not being exceeded in 250 yrs.	Landfill shall not be located in a seismic impact zone.	Maximum acceleration with probability ≥ 90% of not being exceeded in 250 yrs.	--	Maximum acceleration with probability ≥ 90% of not being exceeded in 250 yrs.	Landfill shall not be located in a seismic impact zone.	Landfill shall not be located in a seismic impact zone.
Allows Estimation of Seismic Movement?									
--	Yes, in lieu of a factor of safety of 1.5 under dynamic condition	--	--	--	--	--	--	--	--

Table 5a. Comparison of States: Base Liner System—General

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Permitted Liner Types									
Regulation Section									
40 CFR, Sec. 258.40.	SWRCB Res. 93-62 Section III.A.1.	7 Del. C., Sec. 5.C.2.	NJAC, 7:26-2A.6(e).	20 NMAC, 9.1, Sec. 306A(1)	6 NYCRR, Sec. 360-2.13(f) (1 & 2).	Title 25, Pennsylvania Code, Sec. 273.254.	173-351-300, WAC.	33 CSR, 1-4.5.d.1.C.	NR 504.06 (2 & 3).
Type of Liner									
Composite or any design the approved state finds won't exceed MCLs at the POC until after the end of post-closure care (30 years).	Composite	Single composite, natural (clay), double liner.	Natural geologic, composite, double composite.	Composite	Double composite on base, GM primary plus composite secondary on side slopes.	Double liner – one must be composite, i.e. either composite primary and single secondary. Or, single primary and composite secondary.	Composite (for non-arid areas), No liner, but must satisfy max. contaminant levels (arid areas).	Composite	Composite, clay-lined (not for MSW).

Table 5b. Comparison of States: Base Liner System—Single Clay Liner or Natural Geologic Liner

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Regulation Section									
40 CFR, Sec. 258.40(a)(1).	Not permitted.	7 Del. C., Sec. 5.C.2 (b).	NJAC, 7:26-2A.6(d).	Not permitted.	Not permitted.	Not permitted.	Not permitted.	Not permitted.	NR 504.06 (2).
Minimum Thickness									
--	--	5 ft	3 ft	--	--	--	--	--	5 ft
Maximum Hydraulic Conductivity/Permeability									
--	--	1×10^{-7} cm/s	1×10^{-7} cm/s	--	--	--	--	--	1×10^{-7} cm/s
Condition When Allowed									
Approved state finds that MCL won't be exceeded until after the end of the (30-year) post-closure care period.	--	"where underlying groundwater is not used," "landfill subbase is subject to compaction and settlement such that a synthetic membrane would not be feasible." If on-site soil is to be used, top 5 ft must be excavated and recompacted to meet requirement.	"for a sanitary landfill located in a stable low permeable defined geologic formation having a hydraulic conductivity of less than 1×10^{-6} cm/s…"	--	--	--	--	--	Not allowed for MSW landfills.

Table 5c. Comparison of States: Base Liner System—Single Composite Liner

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Definition									
Regulation Section									
40 CFR, Sec. 258.40	SWRCB Res. 93-62, Sec. III.A.1	7 Del. C., Sec. 5.C.2 (a)	NJAC, 7:26-2A.6(e)	20 NMAC9.1, Sec. 306A(1)	Not permitted.	Not permitted.	173-351-300, WAC	33 CSR, 1-4.5.d.5	NR 504.06 (3)
Upper Component									
Min. 30-mil (min. 60-mil for HDPE) geomembrane	Min. 40-mil (min. 60-mil for HDPE) geomembrane.	Min. 45-mil geosynthetic.	Min. 30-mil (min. 60-mil for HDPE) geomembrane.	Min. 30-mil (min. 60-mil for HDPE) geomembrane.	--	--	Min. 60-mil HDPE (min. 30-mil other) geomembrane.	Min. 60-mil synthetic liner.	Min. 60-mil geomembrane
Lower Component									
2-ft of soil with $k \leq 1 \times 10^{-7}$ cm/s.	Same as federal.	2 ft of clay with $k \leq 1 \times 10^{-7}$ cm/s.	2 ft of compacted clay or admixture liner with $k \leq 1 \times 10^{-7}$ cm/s.	2 ft of soil with $k \leq 1 \times 10^{-7}$ cm/s.	--	--	2 ft of soil with $k \leq 1 \times 10^{-7}$ cm/s.	2 ft of compacted clay with $k \leq 1 \times 10^{-7}$ cm/s.	4 ft of clay with $k \leq 1 \times 10^{-7}$ cm/s.
Other Component									
None	None	None	None	None	None	None	None	Must have the following below the liner: Liner subbase: 6 in. thick with $k \leq 1 \times 10^{-6}$ cm/s. Leachate detection zone: 12 in. thick with $k \geq 1 \times 10^{-3}$ cm/s and pipes.	None
Alternatives									
None	Alternative composite allowed if satisfies performance criteria of 40 CFR, Sec. 258.40 (a)(1) & (c) and 27 CCR, Sec. 20080(b). On slopes too steep for composite liner, may construct a non-composite liner with 60-mil synthetic liner (80-mil if HDPE).	Alternative lower component allowed, when approved by the regulatory agency.	--	--	--	--	May be used provided a demonstration can be made.	--	None

Table 5c (continued). Comparison of States: Base Liner System—Single Composite Liner

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Geosynthetic Component									
Regulation Section									
40 CFR, Sec. 258.40(b)	SWRCB Res. 93-62, Sec. III.A.1	7 Del. C., Sec. 5.C.2 (a)	NJAC, 7:26-2A.7(c)4(iii)]	20 NMAC, 9.1 §306A(1)(a)	Not permitted.	Not permitted.	173-351-300 (2)(a)(ii), WAC	33CSR1-4.5.d.5.B	NR 504.06 (3)
Construction Issues									
--	The minimum construction and testing requirements are included in 27 CCR, Sec. 20324.	--	The minimum construction and testing requirements are included in NJAC, 7:26-2A.7(c)4.	--	--	--	--	Field seams oriented parallel to the line of maximum slope. Be capable of withstanding calculated tensile forces on slopes greater than 25%.	Field seams shall be oriented parallel to contour of slopes > 10%. Specifies min. vehicle load permitted over 1 ft and 2 ft of soil placed over geomembrane. Specifies covering base and lower 10 ft of slope within 30 days.
Other Factors									
--	--	--	Anchor trenches a min. 24 in. from edge of top of slope. Anchor trench 12 to 16 in. deep.	Design must include tensile forces for slopes exceeding 4H:1V, taking into account interface friction.	--	--	--	Anchor trenches a min. 24 in. from edge of top of slope. Anchor trench 12 to 16 in. deep, liner laid across the soil perimeter in the trench and compacting backfill.	Slopes of interior sidewalls cannot be steeper than 3H:1v or flatter than 5H:1V. Anchor trenches shall be designed.
Clay Component									
Regulation Section									
40 CFR, Sec. 258.40 (b)	27 CCR, Sec. 20330(b) & SWRCB Res. 93-62, Sec. III.A.1	7 Del. C., Sec. 5.C.2 (a)	NJAC 7:26-2A.6(e)	20 NMAC, 9.1 § 306A(1)(b)	Not permitted.	Not permitted.	173-351-300 (2)(a)(ii), WAC	33CSR1-4.5.d.5	NR 504.06 (2)
Thickness									
2 ft	2 ft	2 ft	2 ft.	2 ft	--	--	2 ft	2 ft	4 ft
Maximum Hydraulic Conductivity/Permeability									
1×10^{-7} cm/s	1×10^{-7} cm/s	1×10^{-7} cm/s	1×10^{-7} cm/s	1×10^{-7} cm/s	--	--	1×10^{-7} cm/s	1×10^{-7} cm/s	1×10^{-7} cm/s
Construction Issues									
--	The minimum construction and testing requirements are included in 27 CCR, Sec. 20324.	--	The minimum construction and testing requirements are included in NJAC, 7:26-2A.7(c)3.	--	--	--	--	Free from particles larger than 2 in.	Clay components of adjacent liners shall be keyed together. Clay shall be min. 50% passing #200 Also, specifies PI, LL and compaction.

Table 5d. Comparison of States: Base Liner System—Double Liners (Including Double Composite Liners) (General)

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Regulation Section									
Not required.	Not required.	7 Del. C., Sec. 5.C.2 (c)	NJAC, 7:26-2A.6(e)1	Not required.	20NMAC9.1 -2.13(f) (4)	Title 25 Pennsylvania Code, Sec. 273.254 and 273.256	Not required.	Not required.	Not required.
Conditions When It Must Be Used									
--	--	Double liner required "where landfills are underlain by aquifers which are reasonably expected sources of water supply and/or capable of significant contaminant transport to adjacent surface waters."	Double composite required where bedrock is at or near surface and serves as direct source of public community water system.	--	On cell bottoms where slope $\leq$ 25%. For side slopes only geomembrane component of primary liner, plus middle component and secondary composite liner is required.	All landfills.	--	--	--
Configuration									
--	--	Primary synthetic plus clay/GCL. Leachate detection and collection layer. Secondary either synthetic or clay.	Primary synthetic plus clay/admixture. Leak detection and collection layer. Secondary geomembrane plus clay/admixture.	--	Primary synthetic plus clay. Leachate detection and collection layer. Secondary synthetic plus clay.	Primary liner. Leachate detection & collection layer. Secondary liner. Either primary or secondary must be a composite liner.	--	--	--
Primary Liner									
--	--	Min. 30-mil synthetic underlain by a GCL or 2 ft of clay with k$\leq$ 1×10^{-7} cm/s.	Min. 60 mil for HDPE, min. 30 mil for other GM, over 2-ft thick clay or admixture with k$\leq$ 1×10^{-7} cm/s.	--	Min. 60-mil geomembrane, over 18-in. clay or GCL over 12-in. clay k $\leq$ 1×10^{-7} cm/s for the top 6 in., bottom 12 in. should be structural fill (particle size < 1 in.).	2 ft of clay with k $\leq$ 1×10^{-7} cm/s, plus min. 30-mil geosynthetic liner (if secondary is not composite).	--	--	--
Secondary liner									
--	--	Either 30-mil thick synthetic or 5 ft of clay with k$\leq$ 1×10^{-7} cm/s.	Min. 60 mil for HDPE, min. 30 mil for other GM, over 2-ft thick clay or admixture with k$\leq$ 1×10^{-7} cm/s.	--	Min. 60-mil geomembrane, over 24-in. thick clay with k $\leq$ 1×10^{-7} cm/s. Particles < 1 in.	2 ft of clay with k$\leq$ 1×10^{-7} cm/s, plus min. 30-mil geosynthetic liner (if primary is not composite).	--	--	--
Middle component									
--	--	12 in. thick. k $\geq$ 1×10^{-2} cm/s.	Leachate collection system.	--	12-in. LCRS or geonet.	12 in. thick. < 0.5-in. particles. k $\geq$ 1×10^{-2} cm/s.	--	--	--

Table 5d (continued). Comparison of States: Base Liner System—Double Liners (Including Couble Composite Liners) (General)

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Alternatives Reference									
--	--	--	--	--	20 NMAC, 9.1 -2.13(k)	--	--	--	--
Construction and Design Requirements									
--	--	--	--	--	All seams shall be parallel to slope. No horiz. seams within 5 ft from toe. Frequencies for CQA tests specified in Section 360-2.13(j)(3)(i). All geosynthetics on side-slopes shall be designed to withstand calculated tensile forces, including seepage forces expected in primary LCRS.	--	--	--	--

Table 6a. Comparison of States: Leachate System—Primary LCRS

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Regulation Section									
40 CFR, Sec. 258.40.	27 CCR, Sec. 20340 and SWRCB Res. 93-62, Sec. III B.	7 Del. C., Sec. 5.D.	NJAC, 7:26-2A.7(c)vii.	20 NMAC 9.1, Sec. 308.	6 NYCRR, Sec. 360-2.13(g, h).	Title 25, Pennsylvania Code Sec. 273.258.	173-351-300, WAC.	33 CSR, 1-4.5.d.6.	NR 504.06 (3).
Minimum Layer Thickness									
--	--	1 ft	1.5 ft above geomembrane of secondary liner. 1 ft above clay liner.	--	2 ft	1.5 ft (combines protective cover and leachate collection layer).	--	1.5 ft	1 ft
Minimum Hydraulic Conductivity / Permeability									
--		1×10^{-2} cm/s	1×10^{-2} cm/s	--	1×10^{-2} cm/s	1×10^{-2} cm/s	--	1×10^{-3} cm/s	1×10^{-2} cm/s
Maximum Allowable Head on Liner									
<30 cm.	No buildup of hydraulic head on the liner.	1 ft.	1 ft.	1 ft.	1 ft.	1 ft.	1 ft (2 ft in pump sump area only).	1 ft.	1 ft (average leachate head).
Design Flow									
--	Designed, constructed…. to remove twice the max. anticipated daily volume of leachate.	"peak flow" according to "water balance calculations."	"actual flows from the area of drainage at real time events."	--	Max. infiltration rates, based on initial start-up condition—little or no waste. Pipe network designed to remove peak flow from 25-yr, 24-hr storm within seven days.	"sufficient size to transmit leachate that is generated."	--	"expected flow capacity from the drainage area except during storm events."	--
Alternatives Allowed?									
No	May allow dendritic LCRS underlying < 100% of waste for permeable waste allowing free drainage of fluid.	Yes	1-ft sand with k $\geq 1 \times 10^{-2}$ cm/s when alternate liner (compacted clay liner) is used [NJAC, 7:26-2A.6(d)].	Yes	--	Yes	--	--	--
Slope Requirements									
--	--	Min. 2%.	"slope that will provide self-cleaning velocity within the pipe based on actual maximum flows."	Min. 2%.	Min. 2%.	Min. 2%.	--	Min. 2%.	Min. 2% for base. Min. 0.5% for pipe.

Table 6a (continued). Compaison of States: Leachate System—Primary LCRS

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Pipe Specifications									
--	--	--	Min. 6-in. dia.	--	Min. 6-in. dia.	Min. 6-in. dia.	--	Min. 4-in. dia.	Min. 6-in. dia.
Pipe Wall Thickness									
--	--	--	--	Schedule 80 or greater.	--	Schedule 80 or greater.	--	Schedule 40 or greater.	Schedule 80 or greater.
Other Design Factors									
--	Collected leachate cannot be conveyed to any portion of the landfill that does not have a composite liner per SWRCB 93-62 Sec. IIIA	--	Max. pipe spacing = 300 ft. May be increased if geonets are used [NJAC, 7:26-2A.7(d).3(xiii)].	--	All leachate conveyance lines and appurtenances must have double containment, but need not have the required separation from groundwater or bedrock.	--	--	Max. pipe spacing = 100 ft.	Leachate shall flow no more than 130 ft before entering perforated pipe. Details provided in the reg. regarding LCRS trenches, penetration, sump, cushion geotextile. < 5% passing #200.

Table 6b. Comparison of States: Leachate System—Secondary LCRS

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Regulation Section									
Not required.	Not required.	7 Del. C., Sec. 5.C.2c and 5.D	NJAC, 7:26-2A.6(e).1; NJAC, 7:26-2A.7(a).4(ii)	Not required.	6 NYCRR, Sec. 360-2.13(f).	Title 25, Pennsylvania Code § 273.255	Not required.	33 CSR,1-4.5.d.4 [LDS below single composite liner].	Not required.
Minimum Layer Thickness									
--	--	1 ft	--	--	1 ft (granular) or geonet.	1 ft	--	1 ft	--
Maximum Hydraulic Conductivity/Permeability									
--	--	1×10^{-2} cm/s	--	--	1×10^{-2} cm/s (granular) or transmissivity equivalent to that of 1 ft of sand (geosynthetic).	1×10^{-2} cm/s	--	1×10^{-3} cm/s	--
Maximum Allowable Leakage									
--	--	Must not exceed the proposed Action Leakage Rate (which is to be calculated by the operator/ designer).	Each section of LDS of double composite liner must drain to a separate sump capable of isolating potential leaks.	--	Max. allowable leakage rate measured in the secondary LCRS shall not exceed 20 gal per acre per day (based on a 30-day average).	100 gal per acre per day, or more than 10% of leachate generation.	--	--	--
Design Flow									
--	--	"system shall be designed to operate without clogging through post-closure care period."	--	--	--	--	--	--	--
Alternatives Allowed?									
--	--	Yes	--	--	--	--	--	--	--
Slope									
--	--	Min. 2%	--	--	Min. 2%.	Min. 2%.	--	Min. 2%.	--
Pipe Specifications									
--	--	--	--	--	Min. 4-in. dia.	Min. 4-in. dia.	--	Min. 4-in. dia.	--
Pipe Wall Thickness									
--	--	--	--	--	--	Schedule 80 or greater.	--	Schedule 40 or greater.	--
Other Factors									
--	--	--	--	--	< 5% passing #200	Particles <0.5 in.	--	Max. pipe spacing = 100 ft.	--

Table 6c. Comparison of States: Leachate System—Leachate Recirculation

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Regulation Section									
40 CFR, Sec. 258.28	27 CCR, Sec. 20340(g)	7 Del. C., Sec. 5.D.3g	[NJAC, 7:26-2A.7(e)3	NA	6NYCRR Sec. 360-2.17 (j)	Title 25,Pennsylvania Code § 273.274	173-351-200 (9)(a)(ii) , WAC	33CSR1-4.8.a.9	NR 506.13 (2)
Recirculation Allowed?									
Yes	Yes	Yes	Yes	--	Yes	Yes	Yes, only in emergency (see below).	Yes	Yes
Required Liner System to Allow Recirculation									
Composite liner with a leachate collection system.	Composite liner and LCRS by reference to federal regulations.	Composite liner or a double liner.	Composite liner with a leachate collection system.	--	Double liner.	Single composite liner.	Composite liner.	Composite liner and leachate collection system.	Composite liner.
Other Requirements									
May return leachate to same landfill only, and only if composite-lined.	May return leachate to same landfill only, and only to composite-lined portion thereof, as long as the discharge does not exceed the waste's moisture-holding capacity, and is approved by the Water Board.	Must be approved in advance and annually.	Not permitted as a sole leachate disposal option. Permissible as part of an overall leachate management system (that is to enhance biodegradation of landfilled solid waste).	--	Six months of acceptable primary liner performance. Volume of recirculated leachate cannot increase the primary liner leakage rate beyond the 20-gal per acre per day operational threshold (30-day average). Cannot increase the potential for groundwater contamination.	Area must be filled with solid waste. Must have sufficient quantity to absorb leachate. Must be underlain by a leachate collection system. Leachate shall not be a hazardous waste.	Leachate collection system. May accept leachate, condensate, or water resulting from an emergency in disposing of such liquids. Must include demonstration in permit application.	Leachate recirculation is conducted with an approved piping system. Area subject to recirculation is previously filled with solid waste. There is sufficient waste capacity to absorb the leachate.	Must have "efficient leachate collection system." Must be approved.

Table 7a. Comparison of States: Final Cover System—General

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Permitted Final Cover Types									
Regulation Section									
40 CFR, Sec. 258.60	Title 27 CCR §21090(a) & SWRCB Res. 93-62 Attach. 1	7 Del. C., Sec. 5.H	NJAC, 7:26-2A.7(i)	20 NMAC 9.1, Sec. 502A(1)(a)	6 NYCRR, Sec.360 - 2.15(d)	Title 25, Pennsylvania Code, Sec. 273.234	173-351-500, WAC	33 CSR, 1-6.1.e.1	NR 504.07
Minimum Requirements									
1.5-ft soil of $k \leq 1 \times 10^{-5}$ cm/s, or less than k of liner/natural subgrade.	1-ft soil w/ $k \leq 1 \times 10^{-6}$ cm/s or k of bottom liner, whichever is less.	30-mil geomembrane plus geotextile; **or**, 2-ft soil layer.	1.5-ft of $k \leq 1 \times 10^{-5}$ cm/s, or less than k of liner/natural subgrade.	1.5-ft of $k \leq 1 \times 10^{-5}$ cm/s, or less than k of liner/natural subgrade.	For lined landfills operating after 8 October 1993, composite (GM **and** $k \leq 1 \times 10^{-6}$ cm/s soil). [For unlined or lined landfills with liner $k > 1 \times 10^{-7}$ cm/s, either 1.5-ft of soil with $k \leq 1 \times 10^{-7}$ cm/s, or 40-mil geomembrane (60-mil if HDPE) or composite.]	30-mil geomembrane (60-mil if HDPE) [§ 273.256(e) Table 1].	30-mil (60-mil if HDPE) geomembrane **and** 2 ft soil—non-arid areas. 2 ft soil—arid areas.	1 ft of soil with $k \leq 1 \times 10^{-7}$ cm/s.	40-mil geomembrane **and** 2 ft of soil.
Requires Composite Final Cover									
No	No	No	No	No	Only on areas with less than 4H:1V slope Steeper areas receive either GM or soil, not both.	No	Yes (non-arid). No (arid).	No	Yes
Requires Final Cover to Have Hydraulic Conductivity/Permeability Less Than or Equal to That of Liner/Subsoil									
Yes	Yes, or can substitute "throughflow" for "hydraulic conductivity."	Yes	Yes	Yes	No	Permeability less than or equal to the permeability of the primary liner, or $k \leq 1 \times 10^{-7}$ cm/s, whichever is less.	--	Any alternative design must include at least 1.5 ft of earthen material with k≤ that of the bottom liner, or natural sub-soil, or 1×10^{-5} cm/s, whichever is least.	Yes (NR 506.08(3)(a).
Requires Synthetic in Final Cover, If Base Liner Has Synthetic									
Not explicitly, but requires cover k to be ≤ liner k.	Not explicitly, but requires cover k to be ≤ liner k unless designed based on "through-flow."	Yes	Yes	Not explicitly, but requires cover k to be ≤ liner k.	Not explicitly, but all landfills operating after 8 October 1993 are required to have composite cover.	Not explicitly, but requires cover k to be ≤ liner k.	--	Prescriptive cover does not, alternative design does.	Yes
Allows Alternative									
Yes	Yes	Yes	--	Yes	Yes	Yes	--	Yes	Yes

Table 7b. Comparison of States: Final Cover System—Components

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Regulation Section									
40 CFR, Sec. 258.60	27 CCR, Sec. 21090(a) & SWRCB Res. 93-62 Attachment I	7 Del. C., Sec. 5.H	NJAC, 7:26-2A.7(i)	20 NMAC 9.1 , Sec. 502A(1)	6 NYCRR, Sec. -2.15(d)	Title 25, Penn. Code, Sec. 273.234	173-351-500, WAC	33 CSR, 1-6.1.e.1	NR 504.07
Top Soil									
6 in.	--	6 in.	5 in.	6 in.	--	--	6 in.	6 in.	6 in.
Vegetative Cover (in addition to top soil)									
--	12 in.	18 in.	--	--	--	12 in.	6 in.	18 in.	30 in.
Drainage Layer									
--	--	--	6 in. on top of soil. 1 ft on top of GM.	--	--	Yes	--	1 ft of soil or a geocomposite with $k \geq 1 \times 10^{-3}$ cm/s.	1 ft of sand with $k \geq 1 \times 10^{-3}$ cm/s.
Infiltration Control—Geosynthetic									
--	--	Min. 30-mil geomembrane underlain by geotextile.	Min. 30-mil geomembrane (60-mil if HDPE).	--	Min. 40-mil geomembrane (60-mil if HDPE).	Min. 30-mil geomembrane (60-mil if HDPE).	Min. 30-mil geomembrane (60-mil if HDPE) (non-arid).	May be used in lieu of clay, with approval.	Min. 40 mil.
Infiltration Control—Soil									
1.5 ft, with $k \leq 1 \times 10^{-6}$ cm/s, or equal to that of any bottom liner/natural material, whichever is lower.	1 ft, with $k \leq 1 \times 10^{-6}$ cm/s, or equal to that of any bottom liner/natural material, whichever is lower unless designed for "throughflow."	--	1.5 ft, with $k \leq 1 \times 10^{-5}$ cm/s	1.5 ft, with $k \leq 1 \times 10^{-5}$ cm/s, or equal to that of any bottom liner/natural material, whichever is lower	$k \leq 1 \times 10^{-6}$ cm/s – 1.5 ft thick underlying GM only in areas with slopes of 4H:1V or flatter, except for "side slope terraces with slopes of 4% or greater" On slopes 4H:1V or steeper, either 2-ft of soil, or geomembrane only.	--	2-ft, with $k \leq 1 \times 10^{-5}$ cm/s (both arid and non-arid areas)	1 –ft, with $k \leq 1 \times 10^{-7}$ cm/s	2-ft, with $k \leq 1 \times 10^{-7}$ cm/s
Are Both Required?									
No	No	No	Yes, only for landfills that have synthetic liner.	No	Yes, only on areas flatter than 4H:1V.	No	Yes (non-arid areas). No (arid areas).	No	Yes
Gas Venting Layer									
--	--	--	Yes	--	1 ft of soil with $k \geq 1 \times 10^{-3}$ cm/s and max 10% by weight of material passing #200 sieve, gas venting riser pipes (min. 6-in. dia) spaced max of 1 vent per acre [6 NYCRR, Sec. -2.13(p)].	--	--	1 ft of soil or a geocomposite with $k \geq 1 \times 10^{-3}$ cm/s placed directly over the intermediate cover to facilitate gas control.	--

Table 7b (continued). Comparison of States: Final Cover System—Components

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Foundation/Grading Layer									
--	2 ft compacted. May be soil, contaminated soil, or waste, provided it has appropriate engineering properties.	1 ft, may be daily or intermediate cover.	--	--	--	--	--	--	6 in., may be daily or intermediate cover.

Table 7c. Comparison of States: Final Cover System—Application

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Regulation Section									
40 CFR, Sec. 258.60.	27 CCR, Sec. 21090(b) and §21110.	7 Del. C., Sec. 5.C.2 (b).	NJAC, 7:26-2A.7(i).	20 NMAC 9.1, Sec. 502A and A(5).	6 NYCRR, Sec. -2.15(d).	Title 25, Pennsylvania Code, Sec. 273.234.	173-351-500(f) & (g), WAC.	33CSR1-6.1.e.1.	NR 504.06 (2)
Days Since Waste Placement Before Final Cover Must Be Placed									
Closure activities to begin within 30 days and complete 180 days from start.	Closure activities to begin within 30 days and complete 180 days from start. Rolling closure usually required. 5-year delay may be allowed to enhance waste degradation.	180	--	Closure activities to begin within 30 days and complete 180 days from start.	210	365	Closure activities to begin within 30 days and complete 180 days from start.	180	Closure activities to begin within 30 days and be complete 180 days from last waste placement [NR 506:08 (4).
Maximum Slope									
--	1.75H:1V. Slopes steeper than 3H:1V must be verified by stability analyses.	3H:1V	5% or 3H:1V (if low erosion).	Side slopes: 4H:1V.	3H:1V	3H:1V	--	4H:1V	4H:1V
Minimum Slope									
--	3%, unless effective system to prevent ponding is proposed.	--	3%	Top deck: 2 to 5% range allowed.	4%	3%	2 to 5%	3%	5%
Requirement for Benches									
--	15-ft wide bench every 50-ft vertical height.	--	--	--	"run-off diversion terraces" at vertical intervals of 20 ft, required only for landfills built without approved plan to slopes steeper than 3H:1V [6NYCRR Sec. -2.15(k)(1)(ii)].	For slopes steeper than 15%, 15-ft wide terrace every 25-ft vertical distance.	--	"Long slopes must incorporate runoff control measures and terracing in order to minimize erosion." For sites on natural slopes greater than 25%, a slope up to 33% may be considered acceptable if terracing is incorporated every 20-ft vertical.	--
Other Requirements									
--	Slope stability report required in any case, with special validation for slopes steeper than 3H:1V or with geosynthetics.	--	--	--	--	--	--	--	--

Table 7c (continued). Comparison of States: Final Cover System—Application

Allows Alternate Cover									
Federal	**California**	**Delaware**	**New Jersey**	**New Mexico**	**New York**	**Pennsylvania**	**Washington**	**West Virginia**	**Wisconsin**
Yes	Yes, with approval.	Yes, daily and intermediate—with approval.	--	Yes, daily—with approval.	--	--	--	Yes, daily—with approval.	--

Table 8. Comparison of States: Post-Closure Maintenance Requirements

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Section									
40 CFR, Sec. 258.60	27 CCR, Sec. 20950, 21180, 21090, & 21900	7 Del. C., Sec. 5.K.1	NJAC, 7:26-2A.7 (a)5	NMAC, Title 20, Ch.9, Part 1, Subpart 5.502	6 NYCRR, Sec. -2.15(k) (4)	Title 25, Sec. 273.191	173-351-500 (j)(2)(a) , WAC	33 CSR, 1-3.13.b.1	NR 506.17
Minimum Post-Closure Maintenance Period									
30 years (lengthened or shortened on site-specific basis).	30 years, or as long as poses a threat to public health and safety and the environment.	30 years.	30 years.	Not defined.	30 years.	Not defined.	30 years.	30 years.	40 years.
Reporting and Site Review									
Submit post-closure plan including monitoring and maintenance activities, property usage, and contact information.	Post-closure maintenance plans and annual cost estimate; post-closure emergency response plan; initial survey and map required after closure. Iso-settlement maps required every five years after closure	Closure plan including post-closure care.	Closure and post-closure care plan.	Post-closure care and monitoring plan.	Post-closure monitoring and maintenance operations manual.	Closure plan including a description of post-closure monitoring, gas and leachate control, erosion and sediment control, and final cover maintenance.	Submit post-closure plan including monitoring and maintenance activities, property usage, and contact information.	Submit post-closure plan including monitoring and maintenance activities, property usage, and contact information.	Operations manual and design report including schedule for long-term care and financial responsibility.
Systems Maintenance and Operation									
Cover system; LCRS; gas monitoring system.	All containment systems; LCRS; monitoring and collection systems; survey monuments; site security.	Cover system; LCRS; groundwater monitoring system; gas control and recovery system; surface water management system.	Final cover; side slopes; run-on / run-off control; groundwater monitoring wells; gas venting system; LCRS; facility access control system.	Cover system; LCRS; methane and groundwater monitoring systems.	Environmental/ facility monitoring points; vegetative cover; LCRS.	Final cover, LCRS, erosion and sedimentation controls.	Final cover; LCRS; gas monitoring system.	Repair of cover settlement for 10 years after closure; repair of cover material; site monitoring; maintenance and operation of LCRS and gas monitoring system.	Cover system; storm water control system; gas and leachate control features, and gas, leachate, and groundwater monitoring systems.
Monitoring Requirements									
Groundwater monitoring and gas monitoring.	Periodic cover leak search; groundwater, surface water and unsaturated zone; gas monitoring and control system.	Submittal of groundwater quality and gas data required.	Groundwater.	Monitoring performance reports submitted 45 days from the end of each calendar year.	Sampling of environmental/ facility monitoring points with annual and quarterly reports. Quarterly explosive gas monitoring.	Water quality, gas.	Groundwater.	"Monitoring must continue as specified in the monitoring plan required by the permit."	Identification of program required in operations manual, but requirements not specifically defined.

Table 8 (continued). Comparison of States: Post-Closure Maintenance Requirements

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Financial Assurance									
Establish financial assurance for continuous coverage of post-closure care. Includes cost to hire third party to conduct post-closure care, including annual and periodic costs over the entire post-closure period per the post-closure plan.	Requires establishment of an irrevocable fund (or other means) to cover at least the amount of the cost estimate for post-closure maintenance. The cost estimate for post-closure maintenance is the annual cost time 30 years.	Not defined.	Closure and post-closure financial plan submitted to estimate costs, provides a projection of funds available from the escrow account, and specifies alternative funds.	Not defined.	Establish financial assurance for continuous coverage of post-closure care. Includes cost to hire third party to conduct post-closure care, including annual and periodic costs over the entire post-closure period per the post-closure plan.	Assessment of post-closure maintenance costs and means by which funds will be made available to be included in closure plan.	Establish financial assurance for continuous coverage of post-closure care. Includes cost to hire third-party to conduct post-closure care, including annual and periodic costs over the entire post-closure period per the post-closure plan.	Not defined.	Analysis of costs associate with long-term care and method of establishing proof of financial responsibility to be included in operations manual.
Post-Closure Land Use Restrictions									
Shall not disturb the integrity of the final cover, liners, or any other component of the containment system or the function of the monitoring system unless necessary to comply with the requirements of Part 258. [40CFR258.61.(c).(3)]	Shall not disturb the integrity of the final cover, drainage and erosion control systems, and gas monitoring and control systems. [Title 27 CCR §21190.(d)] Construction of structural improvements on top of landfilled areas must meet certain criteria. [Title 27 CCR §21190.(e)] A description of proposed post-closure land uses is required with closure plan. [27 CCR, Sec. 21790.(b)(5)]	Standing water and open burning are prohibited on closed landfill. No activity shall be conducted on closed landfill and access is limited to people maintaining site. [7 Del C. 5.K.3] Require implementation of a post-closure land use plan approved by the Department. [7 Del C. 5.K.4]	Not defined	Use is restricted under the post-closure requirement involving a post-closure care and monitoring plan that maintains integrity of cover, leachate collection system, and methane and groundwater monitoring systems. [NMAC Subpart V.502.A.7.b. and 502.B.1]	Use shall not disturb the integrity of the final cover, liners, or other components of the containment system or the monitoring systems unless necessary to comply with requirements. [6 NYCRR Subpart 360-2.15.(k).(9)]	A post-closure land use plan is required to explain the utility and capacity of the revegetated land to support a variety of alternative uses. [25 Pa 273.191]	Use shall not disturb the integrity of the final cover, liners, or other components of the containment system or the monitoring systems unless necessary to comply with requirements. [WAC 173-351-500.(2).(c).(iii)]	Use shall not disturb the integrity of the final cover, liners, or other components of the containment system or the monitoring systems unless necessary to comply with requirements. [33-1-.6.3.f.3.A]	Prohibited to use waste disposal areas that are no longer in operation for agricultural purposes, the establishment or construction of any building or the excavation of the final cover or waste materials. [NR 506.085]

Table 9. Comparison of States: Groundwater Monitoring Requirements

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Regulation Section									
40 CFR, Sec. 258.50 through 258.58	27CCR, Sec. 20380 through 20430; SWRCB Res. 97-03	7 Del. C., Sec. 5.G	NJAC, 7:14A-9	NMAC Title 20, Ch.9, Part 1, Subpart 8.801	6 NYCRR, Sec-2.11, 2.20	Title 25, Sec. 273.281 through 288.	173-351-400 WAC. 173-200-050 WAC.	33CSR1-4.11	NR 507, 508, 140
Applicability									
Owners of all sanitary landfills. Monitoring programs may be suspended if the owner can demonstrate that there is no potential for migration of hazardous constituents from their landfill to the uppermost aquifer during the active life of the landfill and the post-closure care period.	Owners or operators shall detect, characterize, respond to releases to groundwater, surface water, or the unsaturated zone and shall maintain financial assurance for corrective action for known or foreseeable releases from the unit until the owner or operator can demonstrate that the waste in the unit no longer poses a threat to water quality (in the absence of maintained containment structures).	Owners of all sanitary landfill facilities.	Owners of all sanitary landfills except if the owner can demonstrate that there is no potential for migration of any hazardous constituents from the MSWLF t the uppermost aquifer during the active life of the unit and the post-closure care period.	All new landfills and those operating or closed on or after October 9, 1993. Landfills closed between May 14, 1989 and October 9, 1993 are required to comply with some exceptions. Monitoring programs may be suspended if the owner can demonstrate that there is no potential for migration of hazardous constituents from their landfill to the uppermost aquifer during the active life of the landfill and the post-closure care period.	All landfills require environmental monitoring program. For double liner landfills, the winter sampling period may be omitted once there is a complete understanding of water chemistry and a demonstration of acceptable liner performance is made.	A person or municipality that operates a municipal waste landfill. The owners shall install, operate, and maintain a monitoring system that can detect the entry of solid waste constituents, leachate, contaminants or constituents of decomposition into the groundwater or surface water.	The owners of all landfills who are subject to 173-351 regulations per 173-351-010 (all landfills except those exempt by date or operations)	All landfills and solid waste disposal surface impoundments	All facilities may be required at a minimum to monitor groundwater, the unsaturated zone, leachate, lysimeter fluid, gas, gas condensate, surface water, public or private water supplies, air or other physical features. Facilities in operation before Oct 9, 1993 which received less than 100 tons per day on an annual basis and which ceased accepting solid waste after April 9, 1994, have different requirements.

Table 9 (continued). Comparison of States: Groundwater Monitoring Requirements

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Required Programs									
Includes detection monitoring program, assessment monitoring program (if necessary), and corrective action program (if necessary).	Includes detection monitoring program (DMP), evaluation monitoring program (EMP), and corrective action program (CAP).	Sampling and testing program to determine background concentrations. Sampling and testing repeated semi-annually with report annually.	Groundwater monitoring program; leak detection monitoring program	Includes detection monitoring program and assessment monitoring program. Assessment of Corrective measures program if necessary.	Must establish existing water quality prior to landfilling, operational water quality, post-closure period, and contingency water quality if contamination is detected.	Monitoring plan included in permit application. Groundwater assessment plan prepared and submitted when detected. Contingency water quality monitoring included in the environmental monitoring plan.	Detection monitoring program and assessment monitoring program. Can propose changes or alternative ground water monitoring after the second year of monitoring.	A Phase I Detection monitoring program, Phase II Assessment Monitoring program, and a corrective action assessment and implementation program if required.	Includes baseline groundwater quality sampling, detection groundwater monitoring, water supply well monitoring, lysimeter fluid and leachate monitoring.
Water Quality Protection Standard (Water Standard)									
Established during the creation of the assessment monitoring program for constituents listed in Appendix II that were detected.	Established in the WDRs during DMP; consists of constituents of concern, concentration limits, point of compliance, and all monitoring points.	Established at each site, usually to the maximum contaminant levels (MCLs) for drinking water, unless otherwise specified by the Dept., in conjunction with Data Evaluation requirements.	Established during assessment program.	Established during assessment program.	Levels established in hydrogeologic report (permitting) to trigger contingency water quality monitoring plan.	Levels defined in conjunction with abatement plan.	Determined during assessment monitoring program using the ground water quality criteria of 173-200 WAC.	Established in Phase II for Phase I parameters and those listed in Appendix II.	Levels determined during permit application. Consists of preventive action limits for inorganic monitoring parameters and alternative concentration limits (ACLs).
Constituents of Concern									
Listed in Appendix II of the regulation.	Identified in the WDRs, all waste constituents, reaction products, and hazardous constituents reasonably expected.	Listed in regulation, and from Table 1 when requested by department.	Listed in Appendix A of the regulation and Appendix II of the federal regulations (40 CFR, 258).	Listed in Section 1100, Table I and II.	Constituents listed in the Water Quality Analysis Tables must be included in the operational water quality analysis.	Listed in regulations 273.284, includes organic, volatile organic compounds, and metals.	Listed in Appendix I, II, and III.	Organic and inorganic constituents listed in Appendix I and Appendix II of the regulation, or as defined in facility permit, or as required by the director of WVDOEP.	Included in Appendix I, Table 1 (detection monitoring) and Table 3 (assessment monitoring) of Section 507 of the regulation.

Table 9 (continued). Comparison of States: Groundwater Monitoring Requirements

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Concentration Limits									
MCL, background, or health-based limits, as appropriate.	Background [or concentration limits greater than background (CLGB) based on considerations listed in 20400(d)].	Determined in comparison to background levels and performance standards.	Criteria in NJAC 7:9-6 or 40 CFR 258.55, whichever is more stringent.	For hazardous constituents, assessment monitoring limit (AML) defined as 50% of groundwater protection standard (GWPS). Corrective action limit (CAL) defined as 75% of GWPS. GWPS based on MCL background or health-based alternative, as appropriate.	MCL or background, as appropriate.	MCL, background, or risk-based standard, as appropriate.	Enforcement limits established by the department, or background if it is higher than the enforcement limit.	MCL, background, or health-based limits, as appropriate.	Specified concentration above background as identified in Table 3 of MR 140.20 or approved alternative concentration limit.
Point of Compliance ("POC" for Monitoring)									
Specified by the director of an approved state, or at the waste management unit boundary in unapproved states.	Downgradient limit of landfill unit.	Defined at no more than 150 meters from edge of the furthest downgradient waste cell and must be on waste management facility property.	No more than 150 meters from the actual disposal area and located on land owned by owner of landfill.	Defined as the waste management unit boundary on land owned by the owner of the landfill. An alternative relevant point may be approved.	Wells required along downgradient perimeter of facility (less than 50 ft. from boundary)	Applicable under the abatement plan. Defined at 150 meters of the perimeter of the permitted disposal area or at the property boundary, whichever is closer.	Specified by the jurisdictional health department during the permit process.	Less than 150 m from the waste management unit boundary on land owned by the facility.	Specified under sec. NR 140.22. (2) or (3) as point of monitoring, point of groundwater use, property boundary, or limits of design management zone defined by department.
Compliance Period									
Not in 40 CFR, Part 258.	The active life of the unit plus the closure period; minimum time to conduct water quality monitoring.	Not specifically defined in operating criteria, but required during post-closure.	Active life (including closure) and post-closure care period of landfill.	During the active life and post-closure care period.	During the active life and post-closure care period.	Not specifically defined in regulations.	Active life, closure and post-closure care period.	Active life of the facility, including closure and post-closure periods.	Not specifically defined in regulations.

Table 9 (continued). Comparison of States: Groundwater Monitoring Requirements

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
General Water Quality Monitoring and System Requirements									
Sufficient number of wells at appropriate locations (background and relative point of compliance) and depths to collect representative groundwater samples of uppermost aquifer. Consistent sampling and analysis procedures to ensure accurate representation at all wells. Include procedures and techniques for sample collection, sample preservation and shipment, analytical procedures, chain of custody control, and quality assurance and quality control.	Present groundwater and surface water monitoring system requirements for DMP, EMP, and CAP, alternate background locations, drilling logs, sampling and analytical methods, statistical data analysis methods, data collection and analysis. Sufficient number of (1) background wells to yield groundwater samples of uppermost aquifer, other aquifers, zone of saturation, and perched zones; (2) monitoring points at point of compliance and other locations for earliest detection of impact to uppermost aquifer, other aquifers, zone of saturation, and perched zones.	General sampling plan required created during permit application that includes procedures and techniques for sample collection, preservation, and transport, analytical procedures and quality assurance, and chain of custody control. Sufficient number of wells at appropriate locations (background and relative point of compliance) and depths to collect representative water quality samples.	Sufficient number of wells at appropriate locations (background and relative point of compliance) and depths to collect representative groundwater samples of uppermost aquifer. Sampling and analysis procedures and techniques for sample documentation collection, preservation and shipment, analytical procedures, chain of custody control, and quality assurance and quality control.	Sufficient number of wells at appropriate locations (background and relative point of compliance) and depths to collect representative groundwater samples of uppermost aquifer.	Requirements for reporting of data and a site analytical plan for all monitoring plans including field sampling procedures. Horizontal spacing of wells based on site-specific conditions.	At least one well up-gradient and three down-gradient. Number, location and depth requirements for wells, standards for wells and casings, frequency of sampling and analyses, and reporting requirements defined.	Sufficient number of wells at appropriate locations (background and relative point of compliance) and depths to collect representative groundwater samples of first encountered groundwater conduit or pathway, based on site-specific conditions. Procedures and techniques for sample collection and handling, preservation and shipment, analytical procedures, chain of custody control, quality assurance and quality control, decontamination of drilling and sampling equipment, procedures to ensure health and safety during well installation and monitoring, and well operation and maintenance procedures.	Sufficient number of wells (minimum of 4 – 1 up-gradient, 3 down-gradient) to yield groundwater samples of uppermost aquifer. Specifies alternate background locations, sampling and analytical methods, statistical data analysis methods, data collection and analysis.	Monitoring points determined by facility size, waste types, facility design, and hydrogeologic and geologic setting of the facility. Site-specific requirements to determine up- and down-gradient water quality, gradients, and facility impacts. Minimum four Subtitle D monitoring wells. Water supply well monitoring may also be required.

Table 9 (continued). Comparison of States: Groundwater Monitoring Requirements

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Detection Monitoring Program (DMP)									
Required at a minimum, to include the monitoring of constituents listed in Appendix I, including sampling location and frequencies, and reporting requirements. Minimum semi-annual sampling frequency.	Monitoring parameters to meet requirements of SWRCB Resolution 93-62, 5-year COC monitoring, release notification and response, monitoring system changed. Sampling frequency defined by RWQCB.	Establish background for defined constituents, sampling at least semi-annually. Data evaluation using specified procedures for comparing to water standard. Provide data to department and include in annual report.	Detection monitoring program required for monitoring constituents listed in Appendix A, with sampling semi-annually.	Monitoring for parameters listed in Section 1100, Table I, with minimum frequency of semi-annually.	Operational water quality monitoring included in environmental monitoring plan including requirements for monitoring points, parameters, and reporting requirements. Quarterly sampling required, reduced for double-lined cells.	Report results of monitoring on form provided by Department. Frequency of sampling varies by constituent.	Minimum must include monitoring for constituents in Appendix I and II of the regulation.	Phase I Detection Monitoring Program for all groundwater monitoring wells with different requirements for landfill disposing a specific type of waste (i.e. coal), Monitor semi-annually (or as required by director, but no less than annually).	Semi-annual monitoring of constituents listed in Appendix I, Table I. Water supply well monitoring may also be required.

Table 9 (continued). Comparison of States: Groundwater Monitoring Requirements

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Evaluation Monitoring Program (EMP)									
Assessment monitoring program required whenever there is a statistically significantly increase over background levels. Sampling must be performed for constituents listed in Appendix II. Includes sampling locations and frequencies, and reporting requirements.	Monitoring parameters to meet requirements of SWRCB Resolution 93-62, ongoing monitoring, semi-annual monitoring includes all hazardous constituents detected in ground water, data records, and report changes.	If statistically significant increase, perform confirmation sampling. If confirmed, assess corrective measures.	An assessment monitoring program if statistically significant increase in levels over background is found. Must analyze groundwater for constituents in Appendix II within 90 days and annually. Continue DMP. Assess corrective measures.	An assessment monitoring program if levels are above the AML, including data collection and reporting requirements.	Contingency water quality monitoring plan included in environmental monitoring plan if a significant increase over exiting water quality is detected. Samples need to be analyzed for constituents in the expanded Water Quality Analysis Tables. Includes requirement for sampling frequency and location, and reporting requirements. Create groundwater protection standards for detected constituents.	Specifies the way to determine the existence, quality, quantity, aerial extent, and depth of groundwater degradation, and rate and direction of migration.	An assessment monitoring program must be established if constituent levels exceed background levels. Must analyze for Appendix III constituents. Also must establish a ground water protection standard using 173-200 WAC.	A Phase II Assessment Monitoring Program is required whenever statistically significant increases over background have been detected between background and down-gradient monitoring wells for one or more constituent listed in the regulation. Semi-annual monitoring required.	Submit report to assess cause and significance of exceedance and propose response to comply with preventive action limit. First sample for constituents listed in NR 507, Appendix II or all constituents previously detected in leachate. Annual analysis of leachate for constituents in NR 507 Appendix II. Semi-annual sampling for constituents detected in previous wells or leachate.

Table 9 (continued). Comparison of States: Groundwater Monitoring Requirements

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Corrective Action Program (CAP)									
Required if an Appendix II constituent is detected over groundwater protection standards. Program must meet the minimum requirements of an assessment monitoring program, indicate the effectiveness of the corrective action remedy, demonstrate compliance with ground-water protection standard, implement the corrective action remedy selected, and take any interim measures necessary to ensure the protection of human health and the environment.	Corrective action program to remediation releases from the unit and ensure that the discharger achieves compliance with the Water Standard according to monitoring, schedule, and reporting requirements set forth herein. Semi-annual monitoring includes all hazardous constituents detected in ground water.	Corrective measures assessment evaluates extent and nature of release, contaminant fate, potential receptors, feasible corrective measures, implementation, and recommendation for action.	Establish and implement a corrective action ground water monitoring program that meets requirements of assessment monitoring, indicated effectives of remedy, and demonstrates compliance.	Created if detection levels of any constituent from Table I or II are at or above CAL. Program must use corrective action to ensure remediation and that compliance is achieved.	Corrective Measures Report required if any parameters in expanded parameters list (360-2.11) exceed water quality standard. Report must identify potential corrective measures, address public comment, and select action. Submit workplan within 90 days of approval.	Abatement plan – prepared after the presence of groundwater degradation and analysis indicates that an abatement standard is not met, including at MCL limit for constituents listed under the Federal Safe Drinking Water Act.	If levels exceed ground water protection standards, owners must initiate an assessment, selection, and implementation of corrective measures as required by 173-340 WAC, the Model Toxic Control Act regulation.	An assessment of corrective measures must be performed and implemented if there is a significant increase during the Phase II monitoring until groundwater is compliant with standard established in Phase II.	Response measure selected by DNR based on input of assessment report. Range of possible required actions listed in NR 140.24 (Table 5) and NR 140.26 (Table 6) for exceedance of preventive action limit and enforcement standards, respectively.

Table 10. Comparison of States: Landfill Gas Control Regulations

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Regulation Section									
Title I, III, and V of Clean Air Act: 40 CFR, Chapter I (Subtitle D regulation), Part 258—Criteria for Municipal Solid Waste Landfills 40 CFR, Chapter I, Subchapter C, Part 60, Subpart Cc—Emission Guidelines and Compliance Times for Municipal Solid Waste Landfills 40 CFR, Chapter I, Subchapter C, Part 60, Subpart WWW—Standards of Performance for Municipal Solid Waste Landfills	**Shasta County:** Rule 3:29—Municipal Solid Waste Landfills (This rule adopts the requirements of 40CFR 60, Subpart WWW). **South Coast:** Rule 1150.1 - Control of Gaseous Emissions From Municipal Solid Waste Landfills. **Statewide:** 27 CCR, Article 6.	7 Del C. Chapter 60 Section 5 – Sanitary Landfills.	NJAC 7:26-2 and 2A—Solid Waste Regulations. Referencing: NJAC 7:27 – 5 – Prohibition of Air Pollution.	NMAC Title 20, Chapter 9, Part 1 Solid Waste Management Subpart I through Subpart IV.	6 NYCRR, Subpart 360—Solid Waste Management Facilities.	25 Penn. Code Article VIII. Municipal Waste Chapter 273—Municipal Waste Landfills.	173-351 WAC—Criteria for Municipal Solid Waste Landfills.	Title 33 Legislative Rule Series 1 Solid Waste Management Rule (33-1).	WAC NR 504—Landfill Location, Performance, Design, and Construction Criteria. WAC NR 506—Landfill Operational Criteria. WAC NR 507—Environmental Monitoring for Landfills. WAC NR 514—Plan of Operation and Closure Plans for Landfills.

Table 10 (continued). Comparison of States: Landfill Gas Control Regulations

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Applicability Trigger									
All new, existing, and lateral expansion MSWLF that receive waste after October 1991. [40 CFR, 258.A.1.(b)] MSW landfills constructed, reconstructed, or modified on or after May 30, 1991. [40 CFR, 60.750.(a)]	**Shasta County:** Construction, reconstruction, or modification was commenced before May 30, 1991; and the municipal solid waste landfill has accepted waste at any time since November 8, 1987 or has additional design capacity available for future waste deposition. **South Coast:** Rule applies to each active and inactive landfill. [1150.1(b)] **Statewide:** When the enforcement agency, local fire authority, or CIWMB believes a hazard or nuisance is created by landfill gas, the site will need to be monitored. A routine methane monitoring program must be met to ensure methane standards.	All sanitary landfills. [7 Del C., Sec. 5.E.1.a.]	All facilities shall not result in emissions violations [NJAC 7:26-2.11.(b).5.]	Applies to all municipal or special waste landfills that receive solid waste of any quantity [Subpart IV. 402.]	Applies to landfills constructed or modified, or accepted waste since Nov. 8, 1987 or has additional design capacity, landfills that have design capacity $\geq 2.5*10^6$ Mg and $2.5*10^6$ m^3, or landfills that have a NMOC emission rate of $50x10^6$ g/yr or more [Sec 360-2.21.1.1 to 3]. In Long Island, except clean fill landfills, new landfill located outside the deep flow recharge area and expansions and existing landfill must be designed to minimize migration. [360-8.3.(c)] In Long Island, for clean fill landfills, final cover must include gas-venting layer. [360-8.6.d.4]	All municipal waste landfills [25 Pa 273.1.]	All new MSWLF and those that are not regulated under Subtitle C of RCRA, but not facilities that only receive inert and demolition waste, wood waste, industrial solid waste, or other types of solid waste disposed of in limited purpose landfills. [WAC 173-351-010-(2).(a).]	All solid waste facilities or anyone who is responsible for the processing, composting, recycling, transfer, or disposal of solid waste. [33-1-1.1.]	Applies to all solid waste disposal facilities. [01-01 Wisconsin Statues Chapter 289.01] All landfills that accept municipal solid waste need to be designed with an active recovery system. [NR 504.8.(2)] Landfills which accept only industrial waste or other non-municipal solid waste with potential to generate gas require passive extraction system. [NR 504.08.(3).] Landfills with design capacity > 500,000 yd^3 and have accepted municipal solid waste shall install a system to collect and combust hazardous air. [NR 506.08.(6).]

Table 10 (continued). Comparison of States: Landfill Gas Control Regulations

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Compliance Plan Schedule									
If design capacity >2.5x10^6 Mg by mass or 2.5x10^6 m^3 by volume: Submit collection and control system design plan within 1 year if the NMOC emission rate is >50 Mg/yr [40 CFR, 60.752.(b).(2)]	**Shasta County:** Submit plan within 1 year after determining that NMOC emission rate is ≥50 Mg/yr. [3:29 G.2.] **South Coast:** Submit site-specific collection and control system design plan with applications for permits to construct or permits to operate for landfill activities. [1150.1(d)]	Emissions may require permit from Air Resource Section of Division of Air and Waste Management. [7 Del. C. Sec 5.E.3.d]	Permitted according to Bureau of Air Pollution Control. NJAC 7:27. [7:26-2A.7.(f).2]	--	Submit plan within 1 year if NMOC emission rate > 50 Mg/yr. [Section 360-2.21.c.2.ii.(a)]	Gas monitoring and control plan needs to be included in Phase II of permit application. [25 Pa 273.171.(a)]	--	Proposed method of gas collection must be included in landfill design. [33-1-3.10.a.2]	--
Compliance Deadline									
Install a collection and control system within 30 months after first annual report in which NMOC >50 Mg/yr unless Tier 2 or Tier 3 sampling shows <50 Mg/yr. [40 CFR, 60.36c.(a)] and [40 CFR, 60.752.(2).(ii)]	**Shasta County:** Install system within 30 months after first annual report in which NMOC ≥50 Mg/yr. [3:29 G.3.] **South Coast:** Install and operate collection and control system no later than 18 months after submittal of design plan. [1150.1(d)]	--	Existing landfills need to design when gas levels exceed limit of < 25% LEL at perimeter.	--	Install within 30 months after first annual report in which emission rate ≥ 50 Mg/yr unless Tier 2 or Tier 3 sampling shows emission rate < 50 Mg/yr. [360-2.12.c.2.ii.(b)]	Installed during construction of facilities. [25 Pa 273.292.(c)]	--	--	--

Table 10 (continued). Comparison of States: Landfill Gas Control Regulations

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Performance Requirements									
Concentration of methane gas <25%LEL in facility structures and concentration <LEL at facility property boundary. [40CFR60.258.Subpart C..23] **If accepted waste after Nov 8, 1987, and capacity greater than $2.5x10^6$ Mg or $2.5x10^6$ m^3 design with NMOC of $50x10^6$ g/yr or more:** Control devices must meet the requirements of an open flare design, a reduction in NMOC by 98% by weight, or an enclosed combusted designed to reduce NMOC outlet concentrations to 20 ppmv as hexane, dry basis at 3% O_2 or less. [40 CFR, 60.33c.(c)] and [40 CFR, 60.752.(b).(2).(iii).(B)] Operate collection system so methane concentration less than 500 ppm above background at surface of landfill. [40CFR60.753.(d)]	**Shasta County:** Collect landfill gas and route to control system with 98% by weight NMOC reduction or reduce outlet NMOC concentration to <20 ppmv as hexane at 3% O_2; or process collected gas for sale or use. [3:29 E.2.] [40 CFR 60.752] Operate landfill gas collection system to prevent landfill surface methane concentrations from exceeding 500 ppmv. [40 CFR 60.753] **South Coast:** Collect landfill gas and route to control system designed and operated to reduce NMOC by at least 98% by weight or reduce outlet NMOC concentration to <20 ppmv as hexane at 3% O_2; or process collected gas for subsequent sale or use. Operate landfill gas collection system to prevent concentration of TOC (total organic compounds) measured as methane from exceeding specified limits: • 5% vol. in subsurface sampling probes. ppmv determined by integrated samples.	Concentration in facility structures and at boundary <25% LEL. [7 Del C. Sec 5.E.1.c]	Existing landfills need to design when gas levels exceed limit of < 25% LEL at perimeter. A detection of 25% LEL or any concentration within a structure triggers induced draft or active venting system. [NJAC 7:26 – 2A.7.(f).3]	Concentration of methane should be <25% LEL in facilities and <LEL on boundary. [Subpart IV.402.B.1 and 2]	Collect landfill gas and route to control system that 1) is an open flare design 2) reduced NMOC by 90 weight-percent or when a closed combustion device is used, reduce NMOC by 98% or reduce outlet NMOC concentration to less than 20 ppmv as hexane at 3% O_2. [Section 360-2.21.c.2.ii.(c).(1) and (2)] Closure landfill gas control designed to prevent migration of gases off-site, prevent accumulation of gas >25% LEL in structures, prevent damage to vegetation and control odors. [360-2.15.e] Decomposition gases must be <25% LEL in structures on or off-site, concentration <LEL beyond property line. [Section 360-2.17.f.(1)]	Combustible gas levels <25% LEL in structures on site and <LEL at boundaries. [25 Pa 273.292.(e)] Control gases within site to prevent damage to workers, structures, and occupants of adjacent properties. [25 Pa 273.292.(b)]	Concentration of methane <25% LEL structures and <LEL at property boundary, and concentration <100 ppm in off-site structures. [WAC 173-351-200.(4).(a)] Owners must ensure that unit does not violate requirements by Washington State Implementation Plan or U.S. EPA Section 110 of Federal Clean Air Act. [WAC-173-35-200.5.a]	Concentration of methane or explosive gas shall not extend beyond facility boundary >25% LEL. [33-1-3.1.f] Concentration <25% LEL in structures on property and does not exceed LEL at boundary. [33-1-4.10.a.1.A and B]	Cannot have hazardous emission exceeding limits in control of hazardous pollutants (NR445). [NR504.04.(4).f] All landfills accepting waste shall be designed to prevent migration of explosive gas. [NR504.08.(1)] Concentration <25% LEL in structures; in soils outside limits of filling or air within 200' of landfill boundary < 100% LEL. May require no detection at landfill property boundary. [NR506.7.(4)]

Table 10 (continued). Comparison of States: Landfill Gas Control Regulations

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Performance Requirements (continued)									
	• 500 ppmv determined by instantaneous monitoring at any location on landfill surface. [1150.1(d)] **Statewide:** Methane levels not to exceed 25% LEL in facility structures and LEL at facility property boundary. For closure and post-closure, methane gas generated should not exceed 1.25% by volume in air within on-site structures. Concentration of methane must not exceed 5% by volume in air at facility boundary or alternative boundary. Trace gases should be controlled to prevent adverse acute and chronic exposure to toxic and/or carcinogenic compounds.								
System Design and Testing Requirements									
Monitor each well monthly, for gauge pressure in the gas collection header, well temperature, and nitrogen or oxygen levels. [40CFR60.755.(a).(3) through (6)]	**Shasta County:** If landfill design capacity is greater than 2.5 mil. Mg or 2.5 mil. m^3 collection and control system required compliant with federal requirements. [3:29 Conduct initial performance test of landfill gas control system within 6 months of startup of system. [3:29 G.4.] **South Coast:** Conduct initial source test of landfill gas control system within 60 days after achieving maximum production rate at which facility will be operated, but not later than 180 days after initial startup. [1150.1(d)]	--	Gases sampled prior to design and construction **to define quality and quantity**. [NJAC 7:26-7A.(f).6] And on an as needed basis determined by the Division and the Bureau of Air Quality Engineering per NJAC 7:27. [NJAC 7:26-2A.8..(h).9.i]	--	Closure investigation including explosive gas investigation with 3 rounds of subsurface monitoring. [360-2.15.(a).2.(i) through (iii)]	--	--	--	--

Table 10 (continued). Comparison of States: Landfill Gas Control Regulations

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Monitoring Requirements									
Routine monitoring program based on soil type, hydrogeologic conditions, etc. on a quarterly basis. [40 CFR, 60.258.Subpart C.23.(b).(1) and (2)] Post-closure care must include maintaining and operating gas monitoring system. [40CFR60.258. Subpart F.61.(4)] Sample NMOC concentrations using specified sampling procedures. [40 CFR, 60.754.(a).(2) through (4)] Monitor gauge pressure, nitrogen or oxygen concentrations, and temperature. [40 CFR, 60.756.(1) through (3)] Monitor surface methane concentrations.[40 CFR, 60.755.(c).(1)]	**Shasta County:** Monitor pressure, temperature, nitrogen or oxygen content of landfill gas. Monitor exhaust temperature and landfill gas flow of control device. Monitor landfill surface methane concentrations. [40 CFR 60.756] **South Coast:** Monitor TOC and TAC concentrations in landfill gas. Monitor the exhaust temperature and landfill gas flow of control device. Install and operate subsurface probes along landfill boundary. Perform integrated and instantaneous landfill surface monitoring. [1150.1(e)] **Statewide**: Minimum frequency of monitoring is quarterly, except for landfills that accept less than 20 tons per day. If methane levels exceed LEL, a remediation plan must be implemented. All monitoring probes shall be sampled for methane during the monitoring period. Sampling may be required for trace gases when the EA determines there is a possibility of acute or chronic exposure to toxic or carcinogenic compounds.	Sample at least quarterly and provide analytical results in annual report. [7 Del C Sec 5.E.3.b]	Monitor migration from landfill and samplers located close to toe of slope. [NJAC 7:26-2A.8.(b).9.i] Period gas survey in accordance with NJAC 7:26-2A.8.(h).9 may be substituted for design and construction of wells. [NJAC 7:26-2A.8.(b).9.iii] Methane gas survey performed on a quarterly bases. [NJAC 7:26-2A.8.(b).9.ii] Quarterly monitoring around perimeter of buffer zone of active, annual around entire perimeter and perimeter of all structures. [NJAC 7:26-2A.7.(h).6.(i) though (iv)]	Monitoring based on soil condition, hydrogeologic, etc. at site with minimum being quarterly. [Subpart IV, 402.C.1.a-d,2]	Ongoing gas monitoring program initiated upon initial operation with type and frequency based on soil type, hydrogeology, etc. [360-2.17.f.(2)] Monitoring program included in O & M plan. [360-2.9.(k)] Post closure monitoring quarterly for 30 years. [360-2.15.k.(4)] Sample NMOC levels using specified sampling procedures. [Section 360-2.21.e.1.(ii) through (iv)] Measure gauge pressure, nitrogen or oxygen concentration, and temperature monthly. [360-2.21.g.1.i to iii]	Quarterly during active operations and after closure in accordance with approved plan. [25 Pa 273.292.(d)]	Routine monitoring program based on soil conditions, hydrogeologic, etc. [WAC 173-351-200.4.(b).(i)] Minimum frequency of quarterly. [WAC 173-351-200-4.(b).(ii)]	Must have monitoring program based on soil conditions, hydrogeologic, etc. [33-1-4.10.b.4.(D).ii]	Need monitoring program for closure. [NR 514.06.(7)] Sample quarterly for methane and % oxygen. [NR 507.22.(1)]

Table 10 (continued). Comparison of States: Landfill Gas Control Regulations

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Record-Keeping Requirements									
Operating records with gas monitoring results and any remediation plans, closure and post-closure care plans and monitoring results. 40 CFR, 60.258. [Subpart C.29.(a)] 5 years up-to-date all data including initial design capacity, solid waste in-place, year-by-year waste acceptance rate, life of control equipment, control vendor specifications, maximum gas generation flow rate, average combustion temperature, collection system data, boiler or process heater data, and open flare system data. [40CFR, 60.758]	**Shasta County:** Emissions, quantity of waste-in-place, waste acceptance rate. [3:29 F.] [40 CFR 60.758] **South Coast:** Maintain for at least 5 years all data, including control system vendor specifications, landfill gas flow rates, average combustion temperatures, location and concentration of landfill gas samples, periods of operation of boilers, and process heaters. [1150.1(f)]	Information on monitoring, testing, etc. must be retained by owner or operator until end of post-closure period. [7 Del C. Sec 5.I.3.b]	--	--	7 years up to date, records of design capacity, current amount of solid waste-in-place, year-by-year acceptance rate, control equipment, control device vendor, maximum expected gas generation, collection system data, waste acceptance rate, control system parameters, and operation data. [Section 360-2.21.(i)]	--	Gas monitoring results and remediation plan needs to be kept in operating record. [WAC-173-351-200.10.a.iii]	Include gas monitoring program in on-site operating record. [33-1-4.4.b]. Also include gas monitoring results from monitoring and any remediation plan in facility operating record. [33-1-4.4.c.15.A]	--

Table 10 (continued). Comparison of States: Landfill Gas Control Regulations

Federal	California	Delaware	New Jersey	New Mexico	New York	Pennsylvania	Washington	West Virginia	Wisconsin
Reporting Requirements									
Submit an initial design capacity report, annual NMOC emission rate report and collection and control system design plan. [40 CFR, 60.757(b)] Submit a closure report, and equipment removal report 30 days prior to removal of control equipment. [40CFR, 60.757.(d) and (e)]	**Shasta County:** Initial design capacity report. [3:29 E.2.] NMOC emission rate report initially and annually. 5-year estimates of waste-in-place and waste acceptance rate. Closure report within 30 days of ceasing waste acceptance. [3:29 F.] [40 CFR, 60.757] **South Coast:** Initial source test report within 180 days after startup, annual source test report no later than 45 days after anniversary date of initial source test. Quarterly reports of exceedances of emissions standards no later than 45 days after last day of each calendar quarter. Closure report no later than 30 days after ceasing waste acceptance. Decommissioning report 30 days before well capping or removal or cessation of operation of collection or control equipment. [1150.1(f)] **Statewide**: Sampling results must be reported to the EA within 90 days of sampling.	--	--	--	Initial design capacity report no later than 90 days after construction commences. [Section 360-2.21.h.1.(i)] NMOC emission report initially and annually. [360-2.21.h.2] 5-year estimate and annual estimate of NMOC emission rate. [360-2.21.h.2.i] Final closure plan. [360-2.21.h.4]	--	Annual report including information on explosive gases. [WAC-173-351.11.c.viii]	--	Submit sampling results within 60 days of end of sampling period. [NR507.26.(c)]

Table 11. Country Regulatory Agencies, Websites, and Regulations

Country	Regulatory Agency	Website	Regulation
Australia	Environment Australia Provincial level: New South Wales Environmental Protection Authority (NSWEPA) Victoria: Environmental Protection Authority Victoria	www.erin.gov.au/ www.epa.nsw.gov.au/ www.epa.vic.gov.au/	Victoria: Draft Waste Management Policy (Siting, Design, and Management of Landfills) Victoria: Best Practice Environmental Management—Siting, Design, Operation and Rehabilitation of Landfills[§]
Brazil	Sistema Nacional do Meio Ambiente (SISNAMA)Ministério do Meio Ambiente, dos Recursos Hídricos e da Amazônia Legal		artigo 2º da Resolução CONAMA 01/86ABNT NBR8419, NBR 11682, NBR 13896
European Union	European Environment Agency	www.eea.eu.int/	Council Directive 1999/31/EC[**]
Japan	Ministry of the Environment	www.env.go.jp/	Waste Disposal and Cleansing Law (Law No.137 of 1970, Last amended by Law No. 85 of 1997) Technical Guideline for Landfill Site (1977, Last amended in 1998)
South Africa	Department of Water Affairs and Forestry Department of Environmental Affairs and Tourism	http://www.dwaf.gov.za www.environment.gov.za/	Minimum Requirements Documents, Volumes 1—3. Section 21, National Water Act, 1998 (Act 36 of 1998) Section 20(1) Env. Conservation Act, 1989 (Act 73 of 1989)

[§] All landfills requiring a work approval or licenses must comply with policy, objectives of the BPEM, required outcomes of the BPEM, and suggested measures unless alternatives methods can be shown to meet the policy requirements, or provide an equivalent environmental outcome. [WMP, Part II.15.(2) through (4)]

[**] The member states of the European Union have additional national regulations, such as Germany's: TA Abfall (1991), Technical Instructions for Hazardous Waste; TA Siedlungsabfall (1993), Technical Instructions for Domestic Waste; Deponieverordnung (2002). These regulations are more detailed than the EU Directive. They remain essentially effective as far as they specify stricter requirements.

Table 12. Comparison of Countries: Regulatory Topics Included in Tables 13 through 20

Pre-Processing and Special Handling (Table 13)
Does the Regulation Require Pre-Processing?
Any Other Requirement?
Siting (Table 14)
Separation From Underlying Groundwater
Proximity Restrictions
Allows Alternative?
Alternative Methods
Floodplains
Wetlands
General Design Requirements (Table 15)
Surface Water Drainage System
Design Storm
Final Drainage Plan
Slope Stability Analyses
Slope Stability to Include Containment System?
Acceptable Factor of Safety
Design Seismic Event
Allows Estimation of Seismic Movement?
Base Liner System (Tables 16a,16b,and 16c)
General
Permitted Liner Types
Single Clay Liner
Minimum Thickness
Maximum Hydraulic Conductivity/Permeability
Condition When It Can Be Used
Single Composite Liner and Double Liners
Upper Component
Lower Component
Other Component
Alternatives
Other Factors
Requires Double Composite Liner
Leachate Collection and Removal System (Table 17)
Layer Thickness
Minimum Hydraulic Conductivity/Permeability
Maximum Allowable Head on Liner
Design Flow
Allowable Alternatives
Slope
Pipe Specifications

Pipe Wall Thickness
Other Factors
Final Cover System (Tables 18a, 18b, and 18c)
General
Permitted Final Cover Types
Minimum Requirement
Requires Composite Final Cover
Requires Final Cover to Have Hydraulic Conductivity/Permeability Less than or Equal to That of Liner/Subsoil?
Requires Synthetic in Cover, if Liner Has Synthetic
Allows Alternative?
Components
Top Soil
Vegetative Cover (in addition to top soil)
Drainage Layer
Infiltration Control—Geosynthetic Component
Infiltration Control—Compacted Soil
Foundation/Grading Layer
Requirements
Days Since Waste Placement Before Final Cover Must Be Placed
Maximum Side Slope
Minimum Side Slope
Requirement for Benches
Other Requirements
Allows Alternate Cover?
Post-Closure Maintenance Requirements (Table 19)
Minimum Post-Closure Maintenance Period
Initial Survey and Map
Iso-Settlement Maps
Post-Closure Land Use Restrictions
Landfill Gas Control Regulations (Table 20)
Applicability Trigger
Compliance Plan Schedule
Compliance Deadline
Performance Requirements
System Design and Testing Requirements
Monitoring Requirements
Record-Keeping Requirements
Reporting Requirements

Table 13. Comparison of Countries: Pre-Processing[††] and Special Handling

California	Australia	Brazil	European Union	Japan	South Africa
Regulation Section					
Title 14 CCR §17355	**Victoria:** BPEM 6.5 Waste Pretreatment	NA	NA	Ministry of the Environment notification No.42	NA
Does the Regulation Require Pre-Processing?					
Yes, requires waste tires to be reduced in volume by shredding or other means prior to disposal.	**Victoria**: Requires reduction of long-term risk posed by the waste and to improve general landfill performance to maximize the stability of waste going to landfill. This should be done by separating putrescible fractions from waste, and shred and/or bales wastes.	No	EU-Directive (16) requires reduction of biodegradable waste Art. 5 gives time schedule for maximum biodegradable waste after 5 years to 15 years.[‡‡]	Yes, depends on type of waste.	--
Any Other Requirement?					
--	**--**	--	--	--	--

[††] Example of pre-processing: baling, shredding, biological or thermal pre-treatment, etc.
[‡‡] The amount of degradable organic components of domestic waste is strictly limited after 2005. This requires processing of all domestic waste either by incineration or by mechanical-biological treatment.

Table 14. Comparison of Countries: Siting

California	Australia	Brazil	European Union	Japan	South Africa
Separation From Underlying Groundwater					
Regulation Section					
Title 27 CCR § 20240 (c) & definition of "underlying ground water" in §20164.	**Victoria:** WMP, Part II. 16.	--	Annex I, Directive 1999/31/EC.	--	Sections 4 and 8.4.2, Vol. 2.
Proximity Restrictions					
5 ft (1.5m) from underlying groundwater (includes water level rise due to capillary forces).	**Victoria:** Waste cannot be placed within 2 m above uppermost aquifer.	Minimum distance from: Population: 500m Water source >200m Depth of groundwater level> 3m.	"The location of a landfill must take into account…….. geological and hydrogeological conditions……"	--	At least 2 m (special consideration given to sites other than communal sites or small sites in dry areas).
Allows Alternative?					
Yes	**Victoria:** Yes	--	--	--	Yes. Design of separation distance allowed for sites other than communal sites or small sites in dry areas.
Alternative Methods					
Engineered alternatives (to a prescriptive standard).	**Victoria:** Engineered alternatives.	--	--	--	Application of Waste-Aquifer Separation Procedure (WASP)—a risk assessment procedure for aquifer contamination, consisting of calculation of a site-suitability index for waste disposal.
Floodplains					
Description					
Includes by reference 40 CFR, 258.11 & 258.16	**Victoria:** Not allowed in 100-year floodplain unless can be shown landfill will be protected.	--	--	--	Not permitted in areas below 50-year flood line.
Wetlands					
Description					
Includes by reference 40 CFR, 258.12 in SWRCB Res. 93-62	**Victoria:** Not permitted in high value wetlands including wetlands of international importance. [WMP,Part II, 21.(3).(a)]	--	--	--	Not permitted in wetlands.

Table 15. Comparison of Countries: General Design Requirements

California	Australia	Brazil	European Union	Japan	South Africa
Surface Water Drainage System					
Regulation Section					
Title 27 CCR § 21090 (b)(3) & §20365	NA	NA	Annex I, #3, Council Directive 1999/31/EC	NA	Section 8, Vol. 2
Design Storm					
100-year, 24-hour.	--	Only a general recommendation.	--	--	50-year, 24-hour.
Final Drainage Plan					
Required as part of approved final closure plan.	--	Yes	--	--	Yes
Slope Stability Analyses					
Regulation Section					
Title 27 CCR, Sec. 21750 (f)(5) and Sec. 20310 (g)	NA	NA	Annex I, #3, Council Directive 1999/31/EC	NA	Section 8 and Appendices 8.2 & 8.3, Vol. 2
Slope Stability to Include Containment System?					
Yes	--	Yes	Yes	Site-specific requirements.	Not required for Communal Sites. Required for others.
Acceptable Factor of Safety					
1.5, under dynamic condition, or estimate seismic movement.	--	1.5 static, consideration of dynamic condition not required.	--	Site-specific requirements.	1.25, for all sites other than Communal Sites, when failure through waste is the critical mode of failure.
Design Seismic Event					
MPE	--	Not required	--	Site-specific requirements.	None
Allows Estimation of Seismic Movement?					
Yes	--	Not required	--	Site-specific requirements.	--

Table 16a. Comparison of Countries: Base Liner System—General

California	Australia	Brazil	European Union	Japan	South Africa
Permitted Liner Types					
Regulation Section					
SWRCB Res. 93-62 Section III.A.1	**NSW:** not available **Victoria:** BPEM, 5.3	Guide NB-843	Annex I, #3, Council Directive 1999/31/EC	Technical Guideline for Landfill Site, Article 1, Section 1 (5)	Sections 8.4.3 & 8.3.5, Table 8.1, and Appendix 8.2, Vol. 2
Types of Liner Allowed					
Composite	**NSW:** CCL **Victoria:** Composite or CCL	Composite or natural soil barrier NBR 13896 (ABNT, 1997b).	Natural geological barrier or combination of natural geological barrier and artificial barrier (min. 0.5 m thick).	Composite or natural geological layer.	None at Communal sites. Base layer only at Small Dry Sites. Single clay liner at Small Wet Sites and Medium or Large Dry Sites. Double Clay liner at Medium or Large Wet Sites.

Table 16b. Comparison of Countries: Base Liner System—Single Clay Liner

California	Australia	Brazil	European Union	Japan	South Africa
Regulation Section					
Not permitted	**NSW:** not available **Victoria:** BPEM, 5.3.2	NBR 13896 (ABNT, 1997b)	Annex I, #3, Council Directive 1999/31/EC	Technical Guideline for Landfill Site, Article 1, Section 1 (5)	Sections 8.4.3 & 8.3.5, Table 8.1, and Appendix 8.2, Vol. 2
Minimum Thickness					
--	**NSW:** 0.9 m **Victoria:** 1 m	3 m	1 m	5 m	0.3 m for Small Wet or Medium Dry Sites. 0.45 m for Large Dry Sites.
Maximum Hydraulic Conductivity/Permeability					
--	**NSW:** 1×10^{-9} m/s. **Victoria:** $k \leq 1x10^{-9}$ m/s with both fresh water and $5x10^{4}$ ppm NaCl solution.	1×10^{-8} m/s. If minimum distance to groundwater is at least 1.5 m, $k \leq 5 \times 10^{-7}$ m/s is acceptable, when used with "supplemental impermeabilization."	1×10^{-9} m/s	1×10^{-7} m/s	1×10^{-6} m/s.
Condition When It Can Be Used					
--	--	Performance-based	--	--	Single Clay Liner is permitted only at Small Wet Sites and Medium or Large Dry Sites.

Table 16c. Comparison of Countries: Base Liner System—Single Composite Liner and Double Liners

California	Australia	Brazil	European Union	Japan	South Africa
Regulation Section					
SWRCB Res. 93-62, Sec. III.A.	**NSW:** not available **Victoria:** BPEM, Section 5.3.2, 5.3.3	--	Annex I, #3, Council Directive 1999/31/EC	Technical Guideline for Landfill Site, Article 1, Section 1 (5)	Sections 8.4.3 & 8.3.5, Table 8.1, and Appendix 8.2, Vol. 2
Upper Component					
Min. 40-mil (min. 60 mil for HDPE) geomembrane	**NSW:** None required **Victoria:** Geomembrane	Geomembrane	None required.	Geomembrane	None required.
Lower Component					
2-ft (0.6 m) soil with $k \leq 1 \times 10^{-7}$ cm/s.	**NSW:** 0.9 m soil with $k \leq 1 \times 10^{-9}$ m/s. **Victoria:** 1m of clay with $k \leq 1x10^{-9}$ m/s with both fresh water and $5x10^{4}$ ppm NaCl solution.	3 m of soil with $k \leq 1 \times 10^{-8}$ m/s.	Natural geologic material, min thickness 1 m $k \leq 1 \times 10^{-9}$ m/s.	0.5m CCL with $k \leq 1 \times 10^{-6}$ cm/s, 0.05 m asphalt concrete with $k \leq 1 \times 10^{-6}$ cm/s, or geomembrane overlaid by non-woven fabric (Double geomembrane liner).	Primary and secondary CCL separated by a leak detection and collection layer (LDCL) Primary CCL: 0.6 m with $k \leq 1 \times 10^{-6}$ cm/s. Secondary CCL: 0.15 m with $k \leq 1 \times 10^{-6}$ cm/s.
Other Component					
--	**Victoria:** Leachate collection system located above geomembrane with geotextile above.	--	--	Non-woven fabric placed on the upper component for preventing damage from ultra violet light.	0.15 m thick Leak Detection and Collection Layer (LDCL) overlain by geotextile between the primary and secondary clay liner.
Alternatives					
Alternative composite allowed, if satisfies performance criteria of 40CFR 258.40 (a)(1) & (c) and Title 27CCR §20080(b).	**Victoria:** Engineered alternatives.	It depends from state to state.	If artificial geologic barrier is used, it should have min. thickness 0.5 m.	--	Yes, CCL may be replaced by Geomembrane, GCL or Composite liner, at the discretion of the Department.
Other Factors					
On slopes too steep for composite liner, may construct either a composite liner with 40-mil (60-mil if HDPE) upper liner, or a non-composite liner with 60-mil (80-mil if HDPE).	**--**	--	--	--	--
Requires Double Composite Liner					
No	**NSW:** No **Victoria:** No	No	No	No	No

Table 17. Comparison of Countries: Leachate System—Leachate Collection and Removal System (LCRS)

California	Australia	Brazil	European Union	Japan	South Africa[§§]
Regulation Section					
Title 27 CCR § 20340, in combination with SWRCB Res. 93-62 Sec. III.B.	**NSW:** Not available. **Victoria:** BPEM, 5.3.4.	Regulations vary from state to state. Presently, there is no landfill where the LCRS is collecting all of the leachate.	Annex I, Council Directive 1999/31/EC.	Technical Guideline for Landfill Site, Article 1, Section 1 (5).	Sec. 8.4.4, Tables 8 and 8.1, Appendix 8.2, Vol. 2.
Layer Thickness					
--	**NSW:** There is only a requirement for including a drainage layer in LCRS – specific requirements are site-specific **Victoria:** 0.3 m.		>0.5 m	Requires a drainage layer in LCRS—thickness not specified.	0.15 m
Minimum Hydraulic Conductivity/Permeability					
--	**Victoria:** $1x10^{-3}$ m/s	--	--	--	Not specified, material must be single-sized gravel, 38 to 50 mm in size.
Maximum Allowable Head on Liner					
No buildup of hydraulic head on the liner.	**Victoria:** 0.3 m, may exceed in sump.	--	--	--	--
Design Flow					
Designed, constructed…to remove twice the max. anticipated daily volume of leachate.	--	--	--	--	--
Allowable Alternatives					
May allow dendritic LCRS underlying < 100% of waste for permeable waste allowing free drainage of fluid.	**Victoria:** Engineered alternative	--	--	--	--
Slope					
--	**Victoria:** Liner at 3%, pipes at 1% to sump.	--	--	--	2%
Pipe Specifications					
--	**--**	--	--	--	--
Pipe Wall Thickness					
--	**--**	--	--	--	--
Other Factors					
Collected leachate cannot flow to a non-composite lined portion of the landfill.	**--**	--	--	--	Any leachate drain must be properly lined with 2-mm thick geomembrane liner with joints welded to same specifications as for hazardous waste liners.

[§§] LCRS not required for all communal sites and all dry sites. Required for small, medium, and large wet sites.

Table 18a. Comparison of Countries: Final Cover System—General

California	Australia	Brazil	European Union	Japan	South Africa
Permitted Final Cover Types					
Regulation Section					
SWRCB Res. 93-62 Section Attachment I & Title 27 CCR §21090(a).	**Victoria:** BPEM, 7.1	NA	Annex I, #3, Council Directive 1999/31/EC ***	Technical Guideline for Landfill Site, Article 1, Section 2 (17).	Section 8.4.7, Table 8.2, Appendix 8.2, Vol. 2.
Minimum Requirement					
1-ft (0.3 m) soil	--	No	1-m soil.	0.5 m soil.	0.3 m or 0.45 m soil.
Requires Composite Final Cover					
No	**Victoria:** No	No	No	No	No
Requires Final Cover To Have Hydraulic Conductivity/Permeability[19] Less Than or Equal to That of Liner/Subsoil?					
Yes, or can substitute "through-flow" for "hydraulic conductivity."	**Victoria:** Yes, 75% of liner	No	No	No	No
Requires Synthetic in Cover, If Liner Has Synthetic					
Not explicitly, but requires cover k to be ≤ liner k, unless designed for "through-flow."	--	No	No	No	No
Allows Alternative?					
Yes	**Victoria:** Yes	No	--	Yes	Yes

*** In EU Directive, a final cover system is not required; the decision is left to the member states. In Germany and many other states, final cover systems are required according to national regulations.

Table 18b. Comparison of Countries: Final Cover System—Components

California	Australia	Brazil	European Union	Japan	South Africa
Regulation Section					
Title 27 CCR § 21090(a) & SWRCB Res. 93-62 Attachment I.	**Victoria:** BPEM, 7.1.3.	NA	Annex I, #3, Council Directive 1999/31/EC.	Technical Guideline for Landfill Site, Article 1, Section 2 (17).	Section 8.4.7, Table 8.2, Appendix 8.2, Vol. 2.
Top Soil					
--	**Victoria:** Local soil type and depth or a mix of soils 200 to 300 mm thick.	Yes. (Recommendation 50% sand, 25% silt and 25% clay (at least). Compacted without strength control).	--	--	0.2 m Must be lightly compacted. In arid areas, may be replaced with a layer of natural gravel.
Vegetative Cover (in addition to top soil)					
12-in. (0.3 m).	**Victoria:** 0.5 to >1m, depending on cap components.	Grass	--	--	None, top soil to be planted with local grass and shrubs.
Drainage Layer					
--	**Victoria:** 0.3m is layer if included in cover system.	--	0.5 m	--	--
Infiltration Control – Geosynthetic					
--	**Victoria:** Geotextiles above and below drainage layer; Geomembrane can be included, but placed more than 0.6 m below surface.	No	--	--	--
Infiltration Control – Compacted Soil					
1 ft (0.3 m) , with $k \leq 1 \times 10^{-6}$ cm/s, or equal to that of any bottom liner/natural material, whichever is lower, or design for “through-flow”.	**Victoria:** 0.5 to >0.6m depending on cap components.	No	--	0.5 m, natural soil	None at Communal Sites and Small Dry Sites; 0.3 m with infiltration rate < 0.5 m/yr for Small Wet Sites and Medium or Large Dry Sites; 0.45 m with infiltration rate < 0.5 m/yr for Medium or Large Wet Sites.
Foundation/Grading Layer					
2 ft (0.6 m) compacted. May be soil, contaminated soil, or waste, provided it has appropriate engineering properties.	**Victoria:** 0.3 m.	--	--	--	--

Table 18c. Comparison of Countries: Final Cover System—Requirements

California	Australia	Brazil	European Union	Japan	South Africa
Regulation Section					
27 CCR, Sec. 21090(b)	**Victoria:** BPEM, 7.1.3	--	Annex I, 3.3 EU Directive	Technical Guideline for Landfill Site, Article 1, Section 2 (17).	Section 8.4.7, Table 8.2, Appendix 8.2, Vol. 2.
Days Since Waste Placement Before Final Cover Must Be Placed					
Closure activities to begin within 30 days and complete 180 days from start. Rolling closure usually required. 5-year delay may be allowed to enhance waste degradation.	**--**	--	--	--	Site-specific (specified in permit).
Maximum Side Slope					
1.75H:1V	**--**	No	--	--	30 degrees with horizontal
Minimum Side Slope					
3%, unless effective system to prevent ponding is proposed.	**Victoria:** 5%	No	--	--	3%
Requirement for Benches					
15 ft (4.5 m) wide bench every 50 ft (15 m) vertical height.	**--**	No	--	No	Uninterrupted slope length of no more than 20 m.
Other Requirements					
Slope stability report required in any case, with special validation for slopes steeper than 3H:1V or with geosynthetics.	Slopes greater than 20% need engineering design.	--	--	--	--
Allows Alternate Cover					
Yes, with approval.	**Victoria:** Yes, based on water storage principals.	--	--	Yes	--

Table 19. Comparison of Countries: Post-Closure Maintenance Requirements

California	Australia	Brazil	European Union	Japan	South Africa
Regulation Section					
Title 27 CCR § 20950, 21180, 21090, & 21900.	**Victoria:** BPEM, 7.2 BPEM 7.1.1 Site afteruse.	NA	Article 10 Article 13 Annex III	Guideline for Landfill Site, Article 1, Section 3 (1) to (11).	Sections 12 & 13, Vol. 2, Sections 4-9, Appendices A-F, Vol. 3.
Minimum Post-Closure Maintenance Period					
30 years or as long as poses a threat to public health and safety and the environment.	**Victoria:** Determined by results for monitoring.	--	--	Site specific (Decided on the basis of the groundwater quality).	--
Initial Survey and Map					
Required after closure.	**Victoria:** Included in rehabilitation plan.	Not required.	--	--	--
Iso-Settlement Maps					
Required every five years.	**--**	Not required.	--	--	--
Post-Closure Land Use Restrictions					
Shall not disturb the integrity of the final cover, drainage and erosion control systems, and gas monitoring and control systems. [27 CCR, Sec. 21190.(d)] Construction of structural improvements on top of landfilled areas must meet certain criteria. [27 CCR, Sec. 21190.(e)] A description of proposed post-closure land uses is required with closure plan [27 CCR, Sec. 21790.(b)(5)]	**Victoria:** No restrictions, but recommends not using for water feature.	Not available.	--	Not available.	No restrictions, but will need to be approved.

Table 20. Comparison of Countries: Landfill Gas Control Regulations

California	Australia	Brazil	European Union	Japan	South Africa
Regulation Section					
Shasta County: Rule 3:29—Municipal Solid Waste Landfills (This rule adopts the requirements of 40 CFR 60, Subpart WWW). **South Coast:** Rule 1150.1—Control of Gaseous Emissions From Municipal Solid Waste Landfills **Statewide:** 27 CCR, Article 6	**Victoria:** Environment Protection Act 1970 (EP Act). Draft—Waste Management Policy (WMP), (Siting, Design and Management of Landfills). Best Practice Environmental Management (BPEM)—Siting, Design, Operation, and Rehabilitation of Landfills.[†††] EPA Publication 722, Environmental Guidelines for Reducing Greenhouse Gas Emissions from Landfills and Wastewater Treatment Facilities.	Not available.	**EU:** Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste. **UK:** Landfill Directive Regulatory Guidance note 6.0 (Version 3.0 June 2002). **Germany:** Combined Act implementing the EIA Directive, the IPPC Directive, and other EC Directives on environmental protection; Ordinance on the Environmentally Compatible Disposal of Waste from Human Settlements and on Biological Waste Treatment Plant; Landfill Ordinance.	Law No. 1037 of 1920 - Waste Management and Public Cleansing Law (not available). Ordinance Determining Engineering Standards Pertaining to Final Disposal Site for Municipal Solid Wastes and Final Disposal Site for Industrial Wastes.	The Environmental Conservation Act, 1989 (Act 73 of 1989) – described in: Minimum Requirements for Waste Disposal by Landfill by Department of Water Affairs and Forestry.
Applicability Trigger					
Shasta County: Construction, reconstruction, or modification was commenced before May 30, 1991; and the municipal solid waste landfill has accepted waste at any time since November 8, 1987 or has additional design capacity available for future waste deposition. **South Coast:** Rule applies to each active and inactive landfill. [1150.1(b)] **Statewide:** When the enforcement agency, local fire authority, or CIWMB believes a hazard or nuisance is created by landfill gas, the site will need to be monitored. A routine methane monitoring program must be met to ensure methane standards.	**Victoria:** All landfills must comply with EP Act. [BPEM, 2.2] Landfills that are subject to works approval such as: landfills serving population of 500 or more, disposal sites for solid wastes except for landfills for mining wastes, and those accepting low hazard (category C) Prescribed Industrial Wastes. [BPEM, 2.2] Install a landfill system when emissions are causing or may cause odors, emissions represent or may represent a hazard, or it is necessary to reduce greenhouse gas emissions. [WMP, Part II. 20.(1)]	Not available.	**EU:** A waste disposal site including internal waste disposal sites and permanent (more than one year) sites used for temporary store of waste. [Directive 1999/31/EC. Article 2. (g)] Not applicable to non-hazardous sites with a total capacity not exceeding 15,000 tons or with an annual intake not exceeding 1,000 tons serving islands, or landfill sites in insolated settlements used for waste generation of that settlement only. [Directive 1999/31/EC.Article 3. 4.(a)]	Not available.	All new and operating sites. [Minimum Requirements, p. v] Components of landfill system will vary by classification. [Minimum Requirements, p. 8-12]

[†††] All landfills requiring a works approval or licenses must comply with policy, objectives of the BPEM, required outcomes of the BPEM, and suggested measures unless alternative methods can be shown to meet the policy requirements, or provide an equivalent environmental outcome. [WMP, Part II.15.(2) through (4)]

Table 20 (continued). Comparison of Countries: Landfill Gas Control Regulations

California	Australia	Brazil	European Union	Japan	South Africa
Compliance Plan Schedule					
Shasta County: Submit plan within 1 year after determining that NMOC emission rate is ≥50 Mg/yr. [3:29 G.2.] **South Coast:** Submit site-specific collection and control system design plan with applications for permits to construct or permits to operate for landfill activities. [1150.1(d)]	--	Not available.	--	Not available	Gas and air quality monitoring systems are required if it is found in the initial site investigation that gas migration or accumulation could be a hazard, or if operating a site within 250 m of residential or other structures. [Minimum Requirements, p. 8-4]
Compliance Deadline					
Shasta County: Install system within 30 months after first annual report in which NMOC ≥50 Mg/yr. [3:29 G.3.] **South Coast:** Install and operate collection and control system no later than 18 months after submittal of design plan. [1150.1(d)]	**Victoria:** Design prior to establishing the landfill. [BPEM, Section 5.7.2]	Not available.	--	Not available	System and design must be approved by the Department prior to construction. [Minimum Requirements, p. 8-11]

Table 20 (continued). Comparison of Countries: Landfill Gas Control Regulations

California	Australia	Brazil	European Union	Japan	South Africa
Performance Requirements					
Shasta County: Collect landfill gas and route to control system with 98% by weight NMOC reduction or reduce outlet NMOC concentration to <20 ppmv as hexane at 3% O_2; or process collected gas for sale or use. [3:29 E.2.] [40 CFR, 60.752] Operate landfill gas collection system to prevent landfill surface methane concentrations from exceeding 500 ppmv. [40 CFR, 60.753] **South Coast:** Collect landfill gas and route to control system designed and operated to reduce NMOC by at least 98% by weight or reduce outlet NMOC concentration to <20 ppmv as hexane at 3% O_2; or process collected gas for subsequent sale or use. Operate landfill gas collection system to prevent concentration of TOC (total organic compounds) measured as methane from exceeding specified limits: • 5% vol. in subsurface sampling probes. pmv determined by integrated samples. • 500 ppmv determined by instantaneous monitoring at any location on landfill surface. [1150.1(d)]	**Victoria:** All landfill caps should include mulched material in their caps to enhance the oxidation of any fugitive emissions of landfill gas. [Siting, Design …Section 5.7.1] If ambient methane concentrations of 500 ppm or more, or methane concentrations in bores or confined spaces exceed 1% by volume, landfill gas measures must be implemented. [Siting, Design … Section 5.7.2] Landfill gas flares should be designed to reduce emissions of VOCs excluding methane by 98%. [Siting, Design …Section 5.7.2]	Not available	**EU:** Appropriate measures should be taken to control accumulation and migration of landfill gas. [Directive 1999/31/EC. Annex I.4.1] **Germany:** Once a section of landfill has been filled in, prevent methane emissions. [Ordinance on the Environmentally…. 4.5.1]	Maintenance of the final disposal site should provide ventilation apparatus to discharge gas. [Ordinance … Article 1.3.(16)]	No gas can migrate from the landfill to a structure where it could accumulate and represent an explosion hazard. [Minimum Requirements, p. 6-7] Methane concentrations in atmosphere inside buildings on or near the site should be <25%LEL. [Minimum Requirements, p. 11-4] Methane levels on boundaries must be <LEL in the air above the surface or in the air in a hole dug into the ground. [Minimum Requirements, p. 11- 5] Methane levels >10% LEL in air requires a permanent venting system. [Minimum Requirements, p. 11-5]

Table 20 (continued). Comparison of Countries: Landfill Gas Control Regulations

California	Australia	Brazil	European Union	Japan	South Africa
Performance Requirements (continued)					
Statewide: Methane levels not to exceed 25% LEL in facility structures and LEL at facility property boundary. For closure and post-closure, methane gas generated should not exceed 1.25% by volume in air within on-site structures. Concentration of methane must not exceed 5% by volume in air at facility boundary or alternative boundary. Trace gases should be controlled to prevent adverse acute and chronic exposure to toxic and/or carcinogenic compounds.					
System Design and Testing Requirements					
Shasta County: If landfill design capacity is greater than 2.5 mil. Mg or 2.5 mil. m^3 collection and control system required compliant with federal requirements. [3:29 Conduct initial performance test of landfill gas control system within 6 months of startup of system. [3:29 G.4.] **South Coast:** Conduct initial source test of landfill gas control system within 60 days after achieving maximum production rate at which facility will be operated, but not later than 180 days after initial startup. [1150.1(d)]	--	Not available.	**EU:** All landfills receiving biodegradable waste shall be collected, treated and used. If cannot produce energy, must be flared. [Directive 1999/31/EC.Annex I.4.2]	Not available.	If collected gas is not used for energy, must be flared off. [Minimum Requirements, p. 8-11]

Table 20 (continued). Comparison of Countries: Landfill Gas Control Regulations

California	Australia	Brazil	European Union	Japan	South Africa
Monitoring Requirements					
Shasta County: Monitor pressure, temperature, nitrogen or oxygen content of landfill gas. Monitor exhaust temperature and landfill gas flow of control device. Monitor landfill surface methane concentrations. [40 CFR 60.756] **South Coast:** Monitor TOC and TAC concentrations in landfill gas. Monitor the exhaust temperature and landfill gas flow of control device. Install and operate subsurface probes along landfill boundary. Perform integrated and instantaneous landfill surface monitoring. [1150.1(e)] **Statewide**: Minimum frequency of monitoring is quarterly, except for landfills that accept less than 20 tons per day. If methane levels exceed LEL, a remediation plan must be implemented. All monitoring probes shall be sampled for methane during the monitoring period. Sampling may be required for trace gases when the EA determines there is a possibility of acute or chronic exposure to toxic or carcinogenic compounds.	--	Not available.	**EU:** At least once a year. [Directive 1999/31/EC.Article 12.(b)] Monitoring shall continue for as long as authority considers that a landfill is likely to cause a hazard to the environment. [Directive 1999/31/EC. Article 13.(d)] During operating phase, potential gas emissions and atmospheric pressure must be monitored monthly; every six months during after-care phase. [Directive 1999/31/EC.Annex III.2.4]	Verify that the generation of gas from the landfill site is scarcely observed or that no increase in generation of gas is observed over two years or more. [Ordinance … Article 1.3.(7)]	Gas monitoring is a minimum requirement at all Hazardous and Large landfills, but must be installed at other landfills whenever potential problems exist. [Minimum Requirements, p. 11-4] Monitored at three monthly intervals during the operation and at the discretion of the Department after closure. [Minimum Requirements, p. 11-4] If methane levels between 2% and 20% LEL, then regular monitoring is required. [Minimum Requirements, p. 11-4] Methane levels between 10% LEL and LEL require regular monitoring on boundary. [Minimum Requirements, p. 11-5] Gas monitoring must continue after closure until the Department is satisfied that the landfill gas is no longer a risk. [Minimum Requirements, p. 11-5] Sampling for VOCs must be taken at various positions at the landfill site. [Minimum Requirements, p. 11-5] Air monitoring for hazardous substance emissions will be determine on level of identified risk with a minimum of once per year when activities and waste profiles do not change. [Minimum Requirements, p. 11-6]

Table 20 (continued). Comparison of Countries: Landfill Gas Control Regulations

California	Australia	Brazil	European Union	Japan	South Africa
Record-Keeping Requirements					
Shasta County: Emissions, quantity of waste-in-place, waste acceptance rate. [3:29 F.] [40 CFR 60.758] **South Coast:** Maintain for at least 5 years all data, including control system vendor specifications, landfill gas flow rates, average combustion temperatures, location and concentration of landfill gas samples, periods of operation of boilers, and process heaters. [1150.1(f)]	--	Not available.	--	Not available.	--
Reporting Requirements					
Shasta County: Initial design capacity report. [3:29 E.2.] NMOC emission rate report initially and annually. 5-year estimates of waste-in-place and waste acceptance rate. Closure report within 30 days of ceasing waste acceptance. [3:29 F.] [40 CFR 60.757] **South Coast:** Initial source test report within 180 days after startup, annual source test report no later than 45 days after anniversary date of initial source test. Quarterly reports of exceedances of emissions standards no later than 45 days after last day of each calendar quarter. Closure report no later than 30 days after ceasing waste acceptance. Decommissioning report 30 days before well capping or removal or cessation of operation of collection or control equipment. [1150.1(f)] **Statewide**: Sampling results must be reported to the EA within 90 days of sampling.	--	Not available.	**EU:** Report all monitoring results to authorities to show compliance with permit, at least one a year. [Directive 1999/31/EC.Article 12.(b)]	Not available.	Details of monitoring included in closure report. [Minimum Requirements, p. 12-4] The required monitoring data, the format and the frequency that it is presented to the Departments would be specified in the Permit conditions. [Minimum Requirements, p. 11-3]

Table 21. Selected Regulatory Topics for Further Discussion

States
Separation Between Waste and Highest Groundwater
Engineered Alternatives to Separation From Groundwater
Distance From Wetlands
Distance From Water Supply Wells
Evaluation of General Design Requirements and Submittals
Requirements for Liner Performance Evaluation
Surface Water Design Storm Requirements
Allowance of Natural Geologic Liner Or Single Clay Liner
Design and Construction of Liner Components (Clay and Geosynthetics)
Requirements for Double-Liner Systems
LCRS Design Specifications
Secondary LCRS/Leak Detection System Requirements
Allowance of Leachate Recirculation
Site-Specific Considerations For Cover Systems
Post-Closure Land Use Restrictions
Concentration Limits for Groundwater
Groundwater Monitoring System Requirements
Criteria for Corrective Action
Landfill Gas Control Performance Requirements
Countries
Requirements for Pre-Processing of Waste
Site-Specific Considerations in Location Selection
Multiple Prescriptions for Base Liners Based on Site Conditions
Multiple Prescriptions for Final Covers Based on Site Conditions
Site-Specific Considerations for Post-Closure Period